NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

**THE EFFECTS OF REVERSING SLEEP-WAKE CYCLES
ON SLEEP AND FATIGUE ON THE CREW OF
USS JOHN C. STENNIS**

by

John Loc Nguyen

September 2002

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THE EFFECTS OF REVERSING SLEEP-WAKE CYCLES
ON SLEEP AND FATIGUE ON THE CREW OF USS JOHN C. STENNIS

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ABSTRACT

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EXECUTIVE SUMMARY

As the USS JOHN C. STENNIS supported the war on terrorism, the work schedules of her crewmembers were inverted in order to support night flight operations. The entire crew began working the night shift although actual work schedules were highly irregular with duties performed across all hours of the day and night. From the literature on shiftwork and circadian rhythms, we know that long working hours and inadequacies in the quality and quantity of sleep will degrade overall human performance and may have a detrimental effect on command and control functions.

The purpose of this study is to gain insight into the fatigue levels and sleeping patterns of US Navy sailors on an inverted work-rest schedule during combat operations. Actigraphy, oral temperatures and subjective rating scales were collected on thirty-three personnel aboard the USS STENNIS from 01-04 February 2002. The results indicate that there are profound differences in the quality and quantity of sleep among the sailors in this study. Sailors working topside got significantly less sleep, and more fragmented sleep, than those working belowdecks. This could be an indication that light exposure prior to rack time inhibits the release of melatonin, which in turn hampers sleep quantity and quality. Additionally, this analysis showed that the predicted effectiveness of individuals working topside was clearly degraded.

It is evident that sleep deprivation and fatigue was a major problem for the majority of the participants in this study. Other factors may have contributed to the differences we observed in sleep hours and predicted effectiveness, e.g., working conditions, light exposure levels, type of work performed, health issues, and combat stress. It is important to remember that the sample used in this study may not be representative of the entire population of sailors in the U.S. Navy and that broad generalizations concerning the entire surface warfare community should not be made based on the results of this thesis. However, the fact should not be disregarded that nearly 50 percent of the study population reported that they had not yet adjusted to this reversed work-rest schedule.

Based on the results of this thesis and the knowledge that many sailors and Marines are working in similar conditions, there is an urgent need to improve how we address the issues of sleep and fatigue for our military personnel. Educating military commanders on the consequences of sleep deprivation and ways to combat sleep debt, in order to increase operational effectiveness and enhance safety for future operations, is a major step forward. Given the enormous responsibility, fast pace, and personal sacrifices associated with the war on terrorism, developing strategies for recognizing and managing fatigue is crucial.

I. INTRODUCTION

A. OVERVIEW

According to Dr. Neil Kavey of Columbia University Sleep Center, *People tend to boast about how little sleep they've had. It is macho and dynamic; those who run themselves ragged are often hailed as ambitious comers, while those who insist on getting their rest are dismissed as lazy plodders* (Kavey, 1996).

Human beings operate on about a 24-hour biological clock with a predictable pattern for many parameters of our behavior. Body metabolism is one of many physiological parameters that vary with time of day. In the early morning hours, many physiological systems slow down, as can be seen in the highly predictable drops in body temperature, heart rate, and blood pressure. Many studies have found that "… for most people biological alertness peaks in the mid-morning and early evening; it dips mildly in the afternoon and plummets between midnight and dawn" (Toufexis, 1990). Human performance, as measured by a wide variety of tasks, changes over the course of a 24-hour period. Performance on tasks such as reaction time and vigilance mirror the circadian variations seen in body temperature and other physiological indices.

Circadian rhythms tend to be relatively stable, hence the difficulty seen when attempting to invert human circadian rhythms by things such as trans-Atlantic travel with its resultant jet lag or when shiftworkers work at night and sleep during the day. Even limited exposures to normal photic time cues (daylight/darkness) and normal work/social/sleep schedules (day work/night rest and day wake/night sleep cycles) generally preclude rhythm inversion and impact the amount and quality of sleep. When sleep deprived, people think and move more slowly, make more mistakes, and have difficulty remembering things. Their biological clocks indicate they should be sleeping while their work schedules require them to work at odd hours.

The consequences of sleep deprivation and fatigue can be disastrous as seen in accidents such as the Exxon Valdez oil spill, the Bhopal Union Carbide accident, and the near catastrophe at Three Mile Island. The Navy operates in very unforgiving environments where mistakes can lead to environmental and human casualties. While

many laboratory studies have demonstrated the performance decrements associated with sleep loss (Haslam, 1985), few studies have examined the operational impact of sleep deprivation on enlisted personnel on the surface warfare community in the environment of night operations.

B.   BACKGROUND

Crewmembers and Air Wing 9 of the USS JOHN C. STENNIS (CVN-74) departed port two months ahead of schedule on 12 November 2001, knowing that this deployment to the Arabian Sea was going to be far from routine.   Their mission was to support the War in Afghanistan, code name **Operation Enduring Freedom**. During combat, aircrew members are required to fly a tremendous number of night missions and their circadian rhythms are frequently disrupted by these "night carrier operations." Recognizing this problem, the USS STENNIS instituted a remarkable adjustment in the work and sleep schedules of her entire crew. In order to accommodate the need for night operations by the flight crew and to demonstrate support for this requirement, the work schedule of the entire ship's company was shifted to nights. This schedule required the entire ship to get up at 1800 for breakfast and other daily routines, while working throughout the night and early hours until 1000 when they were allowed to go to bed.

C.   OBJECTIVES

The change in working hours implemented by the USS STENNIS provides a unique opportunity to observe a sample of USN sailors during combat operations to determine if an entire ship's company can successfully invert their circadian rhythms. This study has two purposes: 1) to describe the amount and quality of sleep of a sample of the crew in combat conditions who had inverted work/rest schedules and 2) to attempt to explain any observed differences in sleep patterns in the study population.

D.   PROBLEM STATEMENT

The primary research questions being investigated by this research are:

1. Do the circadian rhythms (as measured by actigraphy) of the sailors aboard the USS STENNIS reflect an adjustment to the reversed work-rest schedule?

2. What factors contribute to the sleep quality and quantity while on the reversed work-rest schedule?

E.   SCOPE, LIMITATIONS, AND ASSUMPTIONS

Data collection for this thesis was limited to thirty-three enlisted crewmembers aboard the USS STENNIS. During flight operations, each watchstander is critical to the success or failure to the ship's mission. For this reason, every effort was made to recruit a cross-section of watchstanders from different departments aboard the ship. Among the 33 volunteers participating in the study, only 24 participants had complete data sets; nine subjects were excluded due to incomplete or invalid data.   The data were collected in a minimally invasive manner to prevent additional interference with the normal duties of the crew.

The study was observational in nature and lacked baseline data or a control group. Through a survey instrument, participants reported symptoms characteristic of sleep deprivation. Though both anonymous and voluntary, the results of this survey could be misleading.   For example, it is possible that many participants would deny falling asleep on watch.   The participants were recruited voluntarily and did not represent a randomly selected sample of the population. Therefore, caution should be used in generalizing the results described in this thesis to the entire surface Navy.

F.   THESIS ORGANIZATION

Chapter II reviews the literature on the major concepts related to sleep deprivation and shiftwork. The methods used in the thesis are presented in Chapter III. Chapter IV covers the analytical strategy and presents the statistical results. Finally, conclusions and recommendations for future research are offered in Chapter V.

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II. LITERATURE REVIEW

A. OVERVIEW

This chapter reviews the literature on normal sleep patterns and circadian rhythms in humans, examines the implications of shiftwork and shift rotation, and discusses the consequences of sleep deprivation on performance and health in the U.S. population. Advances in modern technology have led to round-the-clock operations with humans now working schedules that are tremendously disruptive to their normal sleep cycles. Individuals who work irregular hours often suffer from sleep disorders and disturbances in their domestic and social life, all of which can have a direct impact on their performance, work efficiency and safety. Due to the heightened operational tempo of modern combat, these issues have become increasingly important to the U.S. military.

B. SLEEP

Human beings need to sleep. Sleep is essential and inevitable. The longer someone remains awake, the greater the need to sleep and the more difficult it is to resist falling asleep. The need for sleep varies between individuals, but sleeping for 8 out of 24 hours is common while most researchers agree that 7 to 9 hours sleep is required for optimal performance. Sleep patterns are governed by the circadian rhythm that cycles approximately once every 24 hours. Humans are usually awake during daylight hours and asleep during darkness. Normal sleep is characterized by a general decrease in body temperature, blood pressure, breathing rate, and most other bodily functions.

Throughout an eight-hour sleep cycle, a normal adult experiences predictable sleep stages, commonly described as non-REM and REM (Rapid Eye Movement) sleep. A complete sleep cycle is around ninety minutes in length with transition from Stage 1 through Stage 4 (non-REM) sleep followed by REM sleep, with the cycle then reversing back through Stage 4 to Stage 1 sleep (Folkard and Barton, 1993).

1. Non-REM Sleep

Non-REM sleep consists of four stages that range from light dozing to deep sleep. Throughout this state of sleep, muscle activity is still functional, breathing is low, and

brain activity is minimal. Approximately 75% of the sleep cycle is spent in non-REM sleep. Simple thought processes may be reported if a person is awakened in any stage of non-REM sleep; however, he or she will not usually recall any specific dream. Low voltage EEG and slow rolling eye movements characterize stage 1 of sleep. It is during this stage that, often, a sleeping individual may experience the sensation of falling and jerk suddenly into wakefulness. Only 5% of non-REM sleep is spent in Stage 1. It is the transitional period of very light sleep. Although the muscles and breathing rate begin to relax, the individual can still be awakened easily.

Stage 2 of sleep is characterized by a lack of eye movements, sleep spindles, and K-complexes. This stage is often considered the official onset of consolidated sleep. Approximately 45% of non-REM sleep is spent in Stage 2. During this stage, eye movements stop and brain waves become larger. Stage 3 of sleep is characterized by 20 to 40% of slow wave (delta) sleep. As sleep advances progressively deeper, an individual becomes difficult to arouse. A person spends approximately 12% of non-REM sleep in this stage. During this stage slow wave sleep begins as large and slow delta waves intermingle with smaller, faster ones. Stage 4 is characterized by very deep sleep. Of the roughly 75% of non-REM sleep, approximately 13% is spent in this final stage. A person in one of the two latter stages, either 3 or 4, is harder to wake than a person in Stage 1 or 2. People who wake during deep sleep often feel groggy and disoriented for several minutes. By the time a person shifts into Stage 4, the brain produces delta waves exclusively. More than 50% of Stage 4 sleep is characterized by delta waves (Folkard and Barton, 1993).

2. REM Sleep

Most dreaming takes place during REM sleep. Periodic eyelid fluttering, muscle paralysis, and irregular breathing, body temperature, heart rate, and blood pressure distinguish REM from non-REM sleep stages. REM sleep is also called "paradoxical" sleep because brain wave activity is similar to an awakened state. During REM sleep, the brain blocks the neural signals so that the muscles remain immobile and dreams will not be acted out. Adults spend about 20 - 25% of their sleep cycle in REM sleep. The EEG activity during REM sleep shows mixed frequency and low voltage with occasional bursts of "sawtooth" waves (Folkard and Barton, 1993).

C.   SHIFTWORK

The traditional eight-hour workday of 9 to 5 has become increasingly rare. Workers frequently work longer hours and at differing times.   Studies show that shiftwork and shifts with extended hours can have a significant adverse effect on a worker's health, workplace accident rates, absenteeism and a worker's social life (Monk, 1989). Shiftwork, particularly night work, can have a negative impact on the health and well being of workers. In the short term, working at night can cause sleep disturbances, fatigue, stress, irritability, shift-lag syndrome, psychosomatic troubles, difficulties in family, and social contacts and errors and accidents.   In the long term, there is an increased risk of gastrointestinal, cardiovascular and psychoneurotic diseases, and female shiftworkers can experience adverse effects on their hormonal and reproductive functions and family roles (Griffiths, 1993).

Partial sleep deprivation is the main problem that affects the health of shiftworkers. Night work disturbs the natural circadian rhythm of the human body. Shiftworkers have health problems because this circadian rhythm or internal clock is disturbed. It is not surprising that shiftworkers and extended-hour workers suffer from sleep disturbances and the physiological consequences that result from it. A study by Costa (1996) documented the health consequences of shiftwork.   Factors include increased incidence of:

- Heart disease

- Gastric ulcers and gastrointestinal problems

- Social problems and minor psychiatric disorders

- Increased absenteeism

- Sleep disorders and increased fatigue

- Increased error rates and accident rates

The study also found that certain factors could make workers more susceptible to problems when doing shiftwork or working extended hours. These include:

- Heavy domestic work load

- Psychiatric illness

- A history of alcohol or drug abuse

- Epilepsy

- Diabetes

- Heart disease.

D.   SOCIAL AND DOMESTIC PROBLEMS CAUSED BY SHIFTWORK

Shiftworkers, especially those who have irregular work schedules, complain of many social and domestic problems. One study of shiftworkers focused on German nurses whose work schedules included morning shifts beginning at or before 0600 hours (Bauer, 1993). Participants in this study indicated that married life was made more difficult due to differences in work patterns between partners, and that early starting times were incompatible with having dependent family members, such as young children or elderly parents, at home. Additionally, many nurses expressed dissatisfaction over the social isolation experienced as a consequence of their irregular work hours. Likewise, 8-hour and 12-hour shiftworkers from a North American petrochemical company reported lower levels of satisfaction with the amount of time available to them for personal and family pursuits, as compared to day workers (Jaffe, 1996).

It is not only the worker who experiences social and domestic strain as a consequence of irregular work hours, but also the worker's partner and family. In a study of the perceptions and feelings of shiftworkers' partners, more than 50 percent of respondents indicated that their partner's work schedule disrupted their personal and joint social life, created conflict in their relationship with their partner and limited the amount of contact with their children (Smith & Folkard, 1993). Similarly, a survey of 52 wives of Australian seafarers revealed that 83 percent of the wives experienced stress when their partner was due home and due to return to sea, and 79 percent of children were perceived by their mothers as experiencing stress prior to and after the arrival of their father (Foster & Cacioppe, 1986). These figures suggest that partners of military

members are not immune to the social and domestic strain caused by irregular work schedules.

E.   CIRCADIAN RHYTHM DISRUPTIONS AND SHIFT ROTATIONS

The human circadian rhythm is a well-documented phenomenon. It can be thought of as an internal body clock that is synchronized to a 24-hour period, hence the term "circa" (about) "dian" (a day). It regulates a number of physiological functions such as body temperature, hormone secretion, heart rate, blood pressure, respiration, digestion and mental alertness. Circadian rhythms follow a predictable cosine wave as illustrated in Figure 1.
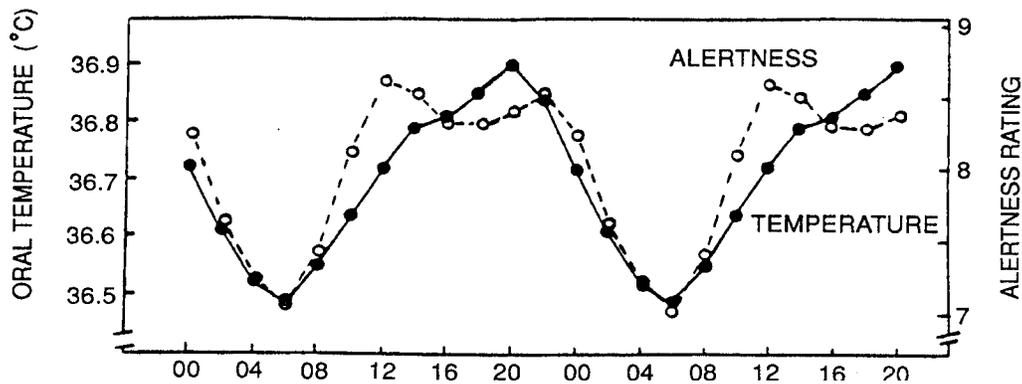
Figure 1.   CIRCADIAN RHYTHMS OF CORE TEMPERATURE AND SUBJECTIVE ALERTNESS (after MONK AND EMBREY, 1981)

During the very early morning hours (or circadian trough), studies have shown that vigilance, productivity, and attention spans plunge dramatically. One study conducted in 1985 by Ebbinghaus found that students learn faster in the morning than in the afternoon (Ebbinghaus, 1985). Other studies found that that human performance peaks between the hours of 1200 and 2100 and rapidly declines between the hours of 0300 and 0600 (Colquhoun, 1982 and Gillooly, 1990).

A person's circadian rhythms can be disrupted when working during unconventional hours where performance tends to drop dramatically. During those times, a person may try to stay at a high level of alertness while their body is demanding sleep. As a result, circadian desynchronosis may occur where the diurnal nature of the human

body is disrupted (Griffith, 1993). Prolonged exposure to such sleep regimens can lead to increased fatigue, mood deterioration, performance decrements, and long-term health consequences (Costa, 1996). While it is possible for the circadian rhythms of an individual to adjust to unusual work routines, the process is slow and is inhibited by the presence of social and environmental "zeitgebers" or timekeepers (Monk, 1989). A study done in 1997 by Folkard found that permanent night workers typically fail to exhibit complete circadian adjustment to their nocturnal work routine (Folkard, 1997).

A variety of approaches have been recommended to address or prevent circadian disruption. Some researchers have recommended that night shifts be permanent or rotated slowly every 3 to 4 weeks (Rayman, 1996). This arrangement should permit a worker's circadian rhythm to adjust to the work-sleep schedule. However, such schedules can produce practical problems, including impacts on workers' families, the need to stay on the schedule during days off, dissatisfaction with permanent assignments to night work, and sleep deficits. It should also be noted that those on a rotating or permanent night shift might have a "post-lunch" dip after the evening meal that may impair performance for up to an hour or more after the meal (Waterhouse, 1997). This performance dip was seen in some night shiftworkers even when the circadian rhythm had adjusted to the new schedule. Other researchers have recommended rapid rotations (shift changes every 2 days) so that the circadian rhythm never changes from its daytime orientation. However, disadvantages of this rapid rotation approach to managing shiftwork include reduced nighttime alertness and poor daytime sleep. Another recommendation is that shift schedules be moved forward slowly to take advantage of the forward-moving tendency of humans to adapt to a 25-hour circadian rhythm (Rayman, 1996).

In some instances, workers effectively self-select a permanent or long rotation that best meet their needs and time orientation. Thus, those with an evening or night orientation (commonly called "owls") may find that night shifts are most appealing (Colquhoun, 1969). Of interest is a study that found that working a whole week of night shifts may pose a safety concern since performance decreases during consecutive nights at work (Niedhammer, 1994). The conflicting information from different studies underscores the difficulties in trying to develop shift rotations that most effectively

reduce performance decrements. As Knauth (1995) notes, there is a lack of conclusive data regarding the effects of permanent versus rotating shifts with respect to alertness, performance, and accidents.

F.   HEALTH CONSEQUENCES OF SLEEP DEPRIVATION

Difficulties in adjusting the circadian rhythm to a night schedule may contribute to night shift hazards, but sleep deficits may also be a major problem. Approximately one-third of the U.S. adult population reportedly suffers from excessive sleepiness due to intentional sleep restriction, sleep disorders, and shiftwork (Caldwell, 1997). Those working the night shift, even if on a permanent night shift, may have significant sleep deficits. Night workers have to attempt to sleep during the day when household or community activities interfere with sleep. Studies have demonstrated that day sleepers sleep for shorter periods, have lighter sleep, and have more interruptions than workers sleeping at night (Rosa and Bonnet, 1990).

Rotating schedules may also contribute to sleep deficits. A study of 635 Massachusetts nurses found more sleep/wake cycle disruptions in those working rotating shifts than those working only day or evening shifts. Those nurses on rotating shifts had twice the odds of nodding off while driving to or from work and twice the odds of a reported accident or error related to sleepiness. Accidents and errors were defined as automobile accidents, medication errors, on-the-job procedural errors, and on-the-job personal injuries (Gold, 1992).

G.   PERFORMANCE DECREMENTS CAUSED BY FATIGUE AND SLEP DEPRIVATION

Research related to sleep loss, performance and fatigue can be categorized into two types: those examining the effects of total sleep loss and those examining the impact of partial sleep deprivation. Military personnel are more susceptible to experiencing reductions in sleep rather than prolonged periods of total sleep loss. In this section, the literature on total sleep deprivation is reviewed first, followed by a review of the effects of partial sleep deprivation.

1. Total Sleep Deprivation

Many sleep studies support the idea that fatigue, mood and performance are adversely affected under conditions of sustained wakefulness. Research was conducted to examine the effects of total sleep deprivation in 20 male naval seamen (How, 1994.) The experiment found significant reductions in mood and performance in tasks requiring cognitive, vigilance, psychomotor and to some extent, physical functions. Performance deteriorated in two stages. An initial drop occurred after 36 to 42 hours of sleep deprivation, followed by a further continuous decline after 66 to 72 hours (How, 1994).

Other research done by McCarthy and Waters in 1997 suggested a reduction in performance on attention demanding cognitive tasks in 71 male undergraduate students with 36 hours of sleep loss. It showed that sleep-deprived individuals were slower to attend to relevant environmental stimuli, exhibited less response to stimuli, lost interest in stimuli more rapidly, and were slower and more variable in their processing of stimuli (McCarthy and Waters 1997). Yet other research found that one night of sleep deprivation could reduce a person's vigilance performance during a 30-minute monotonous tracking task (Bohnen and Gaillard, 1994).

These studies have confirmed how mood and performance deteriorate over periods of sustained wakefulness. In 1991, Babkoff and colleagues evaluated subjective ratings of sleepiness over 72 hours of sleep deprivation in 11 male subjects, and pointed out that both accumulated sleep loss and circadian factors were significant in determining the subject's estimates of sleepiness. Sleepiness ratings progressively increased over the sleepless period and showed distinct circadian oscillations, with the highest ratings of sleepiness occurring between 0200 and 0600 hours, while the lowest ratings were reported at 1000 hours and between 1800 and 2000 hours (Babkoff, 1991).

Similarly, Horne, et al. (1983) discovered a significant decline in intrinsic capacity to detect signals on an auditory vigilance task during 60 hours of sleep loss. Performance fell sharply over the usual sleeping periods and leveled out during the day. The lack of performance deterioration over the day was thought to be a reflection of predictable daytime circadian improvements in performance, which counteract the sleep induced performance decline (Horne, 1983).

More work by Australian researchers Dawson and Reid (1997) has attempted to measure the level of cognitive psychomotor performance impairment induced by sustained wakefulness and compare it to the impairments seen in alcohol intoxication. Forty subjects participated in the study involving two counter-balanced conditions. In one condition subjects remained awake for 28 hours (from 0800 to 1200 hours the following day), while in the second condition subjects consumed 10-15 grams of alcohol at 30-minute intervals (from 0800 hours) until their mean blood alcohol concentration reached 0.10 percent. In both conditions cognitive psychomotor performance was measured using a tracking task, at 30-minute intervals from the start of the session. The results indicated that performance deteriorated significantly in both conditions. By comparing the level of performance impairment observed in both conditions it was shown that after 17 hours of sustained wakefulness, cognitive psychomotor performance had deteriorated to a level equivalent to a blood alcohol concentration of 0.05 percent. Furthermore, 24 hours of sustained wakefulness induced performance decrements equivalent to a blood alcohol concentration of 0.10 percent. As a result, it was concluded by the authors that even relatively moderate sleep loss can produce fatigue-related performance impairments equivalent to, or greater than currently accepted levels for alcohol intoxication (Dawson and Reid, 1997).

It is evident from the above results and findings that fatigue, mood and performance decrements are a common outcome of total sleep loss. Additionally, moderate levels of sleep loss can produce fatigue-related performance impairments equivalent to or greater than decrements induced by a blood alcohol concentration of 0.05 percent.

2. Partial Sleep Deprivation

Studies examining the effects of partial sleep deprivation on mood, fatigue, and performance have produced conflicting results. When 16 young adults (average age, 23 years) had their sleep restricted to approximately 5 hours per night for 7 consecutive nights, mood and performance reductions became apparent after 1 to 2 nights (Dinges, 1997). In particular, subjects' subscale scores for fatigue, confusion, tension, mental exhaustion and stress became elevated across the period of sleep restriction, while vigilance performance significantly deteriorated. Memory performance also showed a

trend towards poorer performance across days of reduced sleep, but was not statistically significant. The results indicate that there was a cumulative effect on performance and mood, as further significant decrements were observed towards the end of the experiment. Following the period of sleep restriction, 2 nights of recovery sleep were required before full performance recovery was achieved (Dinges, 1997).

Other studies showed that restricting sleep to 4 hours per night for 2 and 4 days duration causes performance decrements in cognitive, vigilance and memory tasks (Tilley and Wilkinson, 1984). Placement of the 4 hour block of sleep in either the first or second half of the night had no effect on the level of impairment experienced, suggesting that the performance decrements were a function of sleep loss rather than the changes in sleep composition which occurred due to the different timing of sleep. The study showed that impairment in some tasks still existed after one night of recovery sleep (Wittersheim, 1992). This result supported the theory of Dinges (1997) suggesting that at least 2 nights of recovery sleep are required before a complete recovery is achieved.

Another study done by Morris and Miller in 1996 reported that performance, as measured by error rates, significantly deteriorated over the first 3.5 hours of a 4-hour simulator flight in 10 experienced pilots. The pilots averaged only 2.4 hours sleep during the previous night. Pre and post-flight scores of subjective fatigue, workload and sleepiness increased although only the first two of these measures reached statistical significance (Morris and Miller, 1996). On the day after the simulated flight, subjects reported higher than normal levels of fatigue despite having had an extended period of recovery sleep. This latter finding once again indicates that recovery from partial sleep deprivation is incomplete after one night of sleep.

In contrast, Blagrove et al. (1995) examined the effects of chronic sleep deprivation in 3 groups of young adults and noted no performance decrements in logical reasoning or auditory vigilance tasks, as compared to a control group. However, one group of subjects, whose sleep had been limited to 4.3 hours per night for 4 days, did perform worse on a task requiring focused attention, thereby suggesting they were more easily distracted (Blagrove, 1995). Caution should be used in accepting these results, however, as the performance tests were conducted only 3 to 6 times per week for 5 to 20

minutes at a time. For this reason, it is thought that subjects were probably able to increase their effort and overcome the effects of sleep deprivation for the short duration of the testing sessions. Given that most jobs would involve a greater workload than that used in the investigation, the relevance of this study to the real world is questionable.

Angus et al. (1992) reviewed a number of field studies that examined the performance of military personnel during sustained operations in which sleep was limited. This study indicated that when an average of 4 or more hours of sleep per day was attained, performance remained stable. It is possible that these unexpected results were due to the high levels of motivation and dedication often exhibited by military personnel. Subjects may have exerted more effort and been able to actively overcome the effects of sleep deprivation for the limited period of the study.

In summary, the effects of sleep deprivation seem to be cumulative, as performance and mood become progressively worse with increased sleep deprivation. This finding is consistent with evidence suggesting that insufficient amounts of sleep obtained over several consecutive days leads to a cumulative sleep debt (Folkard, 1996). It also appears that at least two nights of recovery sleep are required before full recovery from partial sleep deprivation is achieved.

H. THE SLEEP, ACTIVITY, FATIGUE, AND TASK EFFECTIVENESS MODEL (SAFTE)

The Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model (see Figure 2) depicts how circadian rhythms and sleep/wake patterns influence cognitive capacity and risk of performance error. The model integrates quantitative information about (1) circadian rhythms as shown in metabolic rates; (2) cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness; and (3) cognitive performance effects associated with sleep inertia to produce a 3-process model of human cognitive effectiveness (Hursh, 2001).

Schematic of SAFTE Model
Sleep, Activity, Fatigue and Task Effectiveness Model
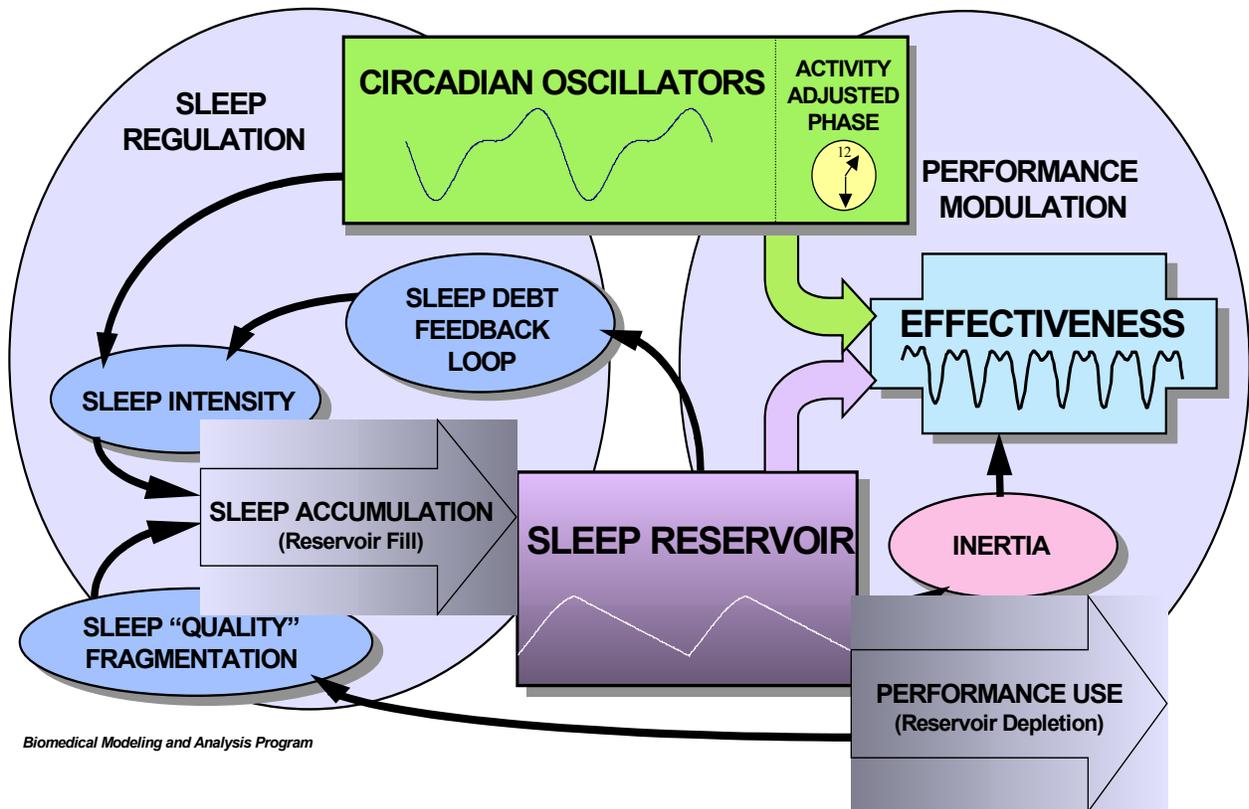
Figure 2.   SAFTE MODEL (HURSH, 2001)

One of the strength of the SAFTE model is that it predicts the normal decline in sleep intensity over the sleep period and normal equilibrium of performance under less than optimal schedules of sleep. It can also predict the detrimental effects of sleep fragmentation and multiple interruptions in sleep. It integrates a multi-oscillator circadian process that incorporates a prediction of the 24-hour asymmetrical cycle of performance. Another strength is the ability to predict the mid-afternoon dip in performance, as well as the more predominant nadir in performance that occurs in the very early morning. Finally, it can predict circadian variations in sleep quality, limitations on performance under schedules that require daytime sleep, sleep inertia that

is proportional to sleep debt, and temporary "jet lag" effects and adjustment to new time zones or shiftwork (Hursh, 2001).

I.   MELATONIN

Melatonin, a naturally occurring hormone secreted by the pineal gland of the brain, shows a regular daily pattern of increase in the late evening, peaking during the night, and declining in the early morning and over the course of the day. It has been shown to promote sleep in human subjects. Its release is inhibited by environmental light and stimulated by darkness, hence, melatonin production peaks at night. Recently, melatonin has received much publicity for its ability to regulate natural sleep patterns and is available in the U.S. as a supplement in most health food stores.
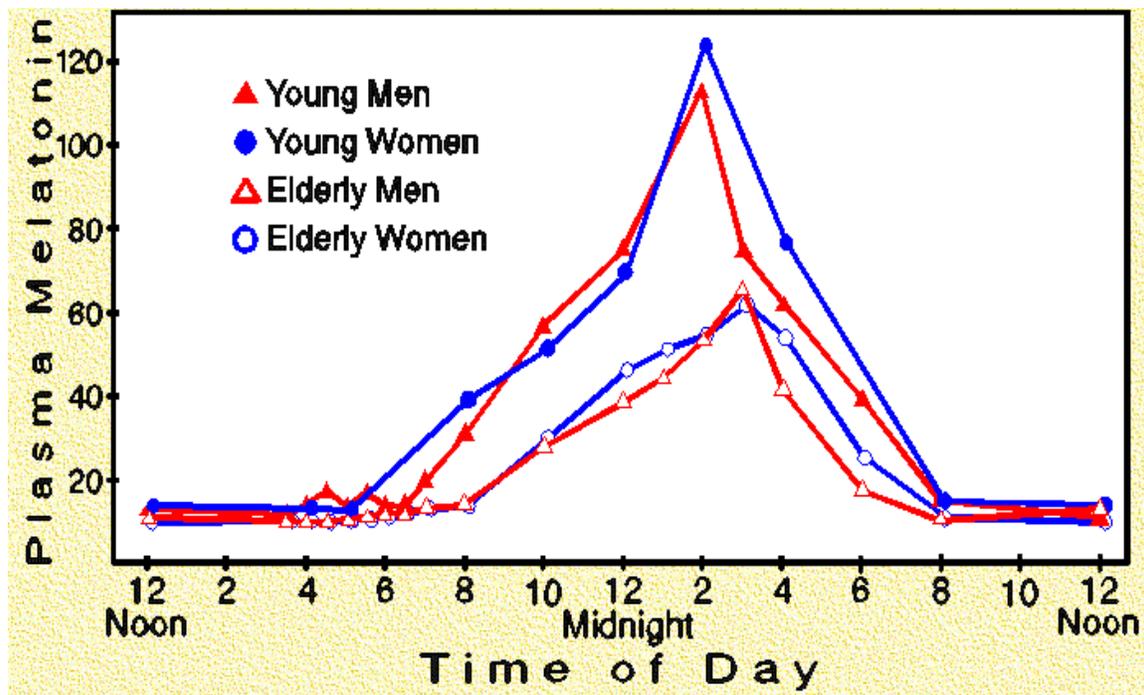
Figure 3.   MELATONIN LEVELS OVER A 24-HOUR PERIOD (after DEAN, 1993)

As seen from Figure 3, melatonin levels peak about 2 a.m. in normal, healthy young people and about an hour later at about 3 a.m. in elderly people. The peak amount of melatonin released in the bloodstream of the elderly is only half that seen in young adults. Melatonin levels are consistently low for all populations during the day. At

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sunset, the cessation of light triggers neural signals, which stimulates the pineal gland to begin releasing melatonin. This rise continues, eventually peaking around 2 A.M. (3 A.M. for the elderly) after which it steadily declines to minimal levels by morning. Dean (1993) states that the delay in timing and decrease in intensity of the melatonin pulse is one common manifestation of the aging process. The melatonin pulse regulates many neuroendocrine functions. When the timing or intensity of the melatonin peak is disrupted (as in aging, stress, jet-lag, or artificial jet-lag syndromes), many physiological and mental functions are adversely affected. The ability to think clearly, remember key facts, and make sound decisions can be profoundly hampered by these upsets in the biological clock.

Further review by Dean (1993) defines jet lag as a condition caused by desynchronization of the biological clock. It is usually caused by drastically changing the sleep-wake cycle, as when crossing several time zones during east-west travel, or when performing shiftwork. Jet lag is characterized by fatigue, early awakening or insomnia, headache, fuzzy thinking, irritability, constipation, and reduced immunity. The symptoms are generally worse when flying in an easterly direction, and it may take as long as one day for each time zone crossed in order to fully recover. Circadian disturbances can easily result from conditions other than jet travel. Artificial jet lag can be induced by working night shifts, working rotating shifts like physician-interns, management trainees for 24-hour businesses, and soldiers under battle-alert conditions, or by staying up all night studying for an exam.

Several studies indicate that supplemental melatonin taken in the evening will rapidly reset your biological clock and almost totally alleviate or prevent the symptoms of jet lag. The ability of melatonin to alleviate jet lag was demonstrated in a study of 17 subjects flying from San Francisco to London (eight time zones away). Eight subjects took 5 mg of melatonin, while nine subjects took a placebo. Those who took melatonin had almost no symptoms of jet lag. Six out of nine placebo subjects scored above 50 on the jet lag scale, while all of the melatonin subjects scored below 17 (Arendt, 1986).

Most people sleep well with melatonin, and wake up the next day refreshed with no symptoms of jet lag (Claustrat, 1992). They report that it helps them get to sleep and

helps them sleep more soundly. It also makes them more alert the next day and even lessens mid-afternoon tiredness. In all cases, melatonin should be taken before going to bed preferably before midnight (local time) when the pineal gland would naturally release melatonin. Taking melatonin at night or before the normal bedtime has been seen to help restore and maintain normal circadian metabolic rhythms for shiftworkers (Dean, 1993).

J. FATIGUE COUNTERMEASURES: PREVENTION OF SLEEP-INDUCED PERFORMANCE IMPAIRMENT

The majority of evidence indicates that sleep deprivation causes a cumulative deterioration in mood, fatigue and performance, and that at least 2 nights of recovery sleep are required before these attributes are restored to baseline levels. In a military context, it is not feasible to completely eliminate this sleep debt since most military personnel experience frequent periods of sleep loss as a result of their work schedules. Additionally, the opportunity for complete recovery between work assignments may not be available.

The alternative is to initiate procedures to assist in overcoming performance impairments (commonly called "fatigue countermeasures"). Educating military commanders on the consequences of sleep deprivation and ways to combat sleep debt in order to optimize their personnel's performances is a major step in the process. To reduce the incidence of desynchronized circadian rhythms, commanders should consider gradually phasing in any operation that requires rotation of personnel from a day to night watch operation. Finally, work-rest schedules should be altered away from the four-on, four-off rotation because this schedule does not allow for a continuous sleep period of at least 4.5 – 5.5 hours of continuous sleep (Johnson, 1984).

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III. METHODOLOGY

A. OVERVIEW

The objective of this thesis is to evaluate the circadian rhythms of sailors aboard USS JOHN C. STENNIS who are experiencing an inverted work/rest schedule. This thesis analyzes 72 hours of data collected using continuous measures of actigraphy, oral temperatures, reported sleepiness and activity levels collected every three hours while participants are awake and compares these data with models extracted from the literature. The analysis will determine if the inversion of their schedules from daytime to nighttime operations had any effect on sleep patterns and fatigue levels of the study participants.

B. COLLECTION

1. Actigraphs

The instrument used to collect objective estimates of sleep was a wrist activity monitor (brand name Actigraph), which uses an accelerometer to record body movement or physical activity. The type used in the research was the Sleep-O Watch (see Figure 4).

Figure 4.   SLEEP-O ACTIGRAPH

In the standard configuration, this model can collect single mode (either Zero Crossing (ZC), Time-Above-Threshold (TAT), or Proportional Integrating Measure (PIM)), or can be run in Tri-mode state and simultaneously collect all three types of data. (Zero Crossing mode measures frequency of movement. Time-Above-Threshold is a

measurement of time spent in motion or duty cycle. Proportional Integrating Measure is the measure of activity level or vigor of motion.) Tri-mode configuration was used in the research although ZCM was the mode used for all subsequent actigraphy analyses. Upon completion of the research period, each watch was collected and data were downloaded to a personal computer using a standard AMI, Inc., OS2K Reader interface.

2. AMI ACT Millennium

The software used to initialize and download actigraphs is called ACT 2000 (see Figure 5), which is developed by Ambulatory Monitoring, Inc.
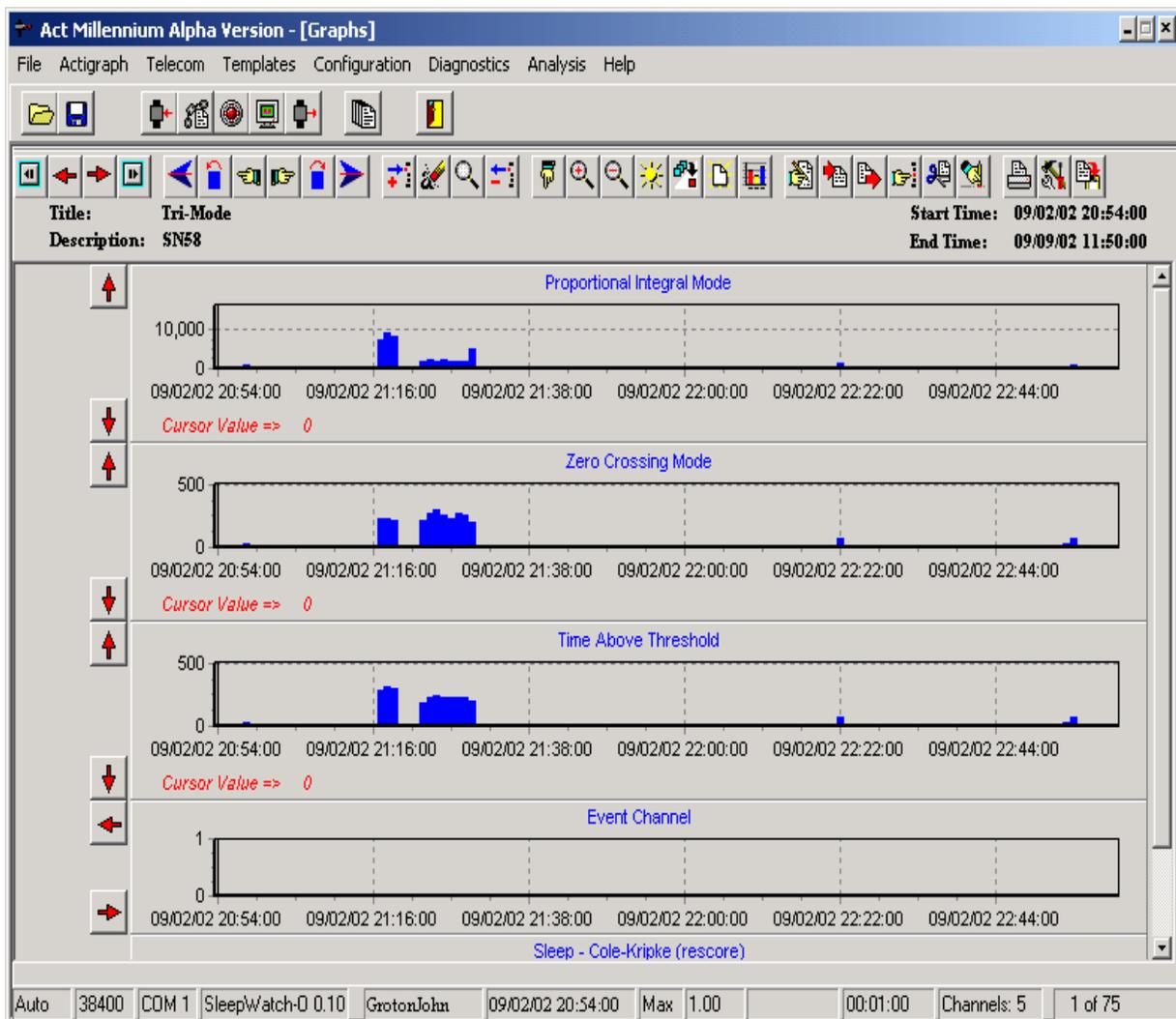
Figure 5.   ACT MILLENNIUM

Prior to initializing or downloading data, ACT2000 is configured to match the existing hardware. Appendix A details steps for configuration. The next step is initializing (Appendix B) which sets up the actigraph to begin recording data. Finally, actigraph data were downloaded (Appendix C) immediately after 72 hours of data collection. Upon completion, actigraphy files were saved as "actigraph data file" (.dat) for use as raw data and "AMI file without application area" (.ami) for use in further analysis with the Action-W (see Appendix L) circadian rhythm and research software.

3. Action-W Version 2 (AW2)

The circadian rhythm research software used for statistical analysis of the actigraphy data is called Action-W Version 2 (see Figure 6), which is developed by Ambulatory Monitoring, Inc.
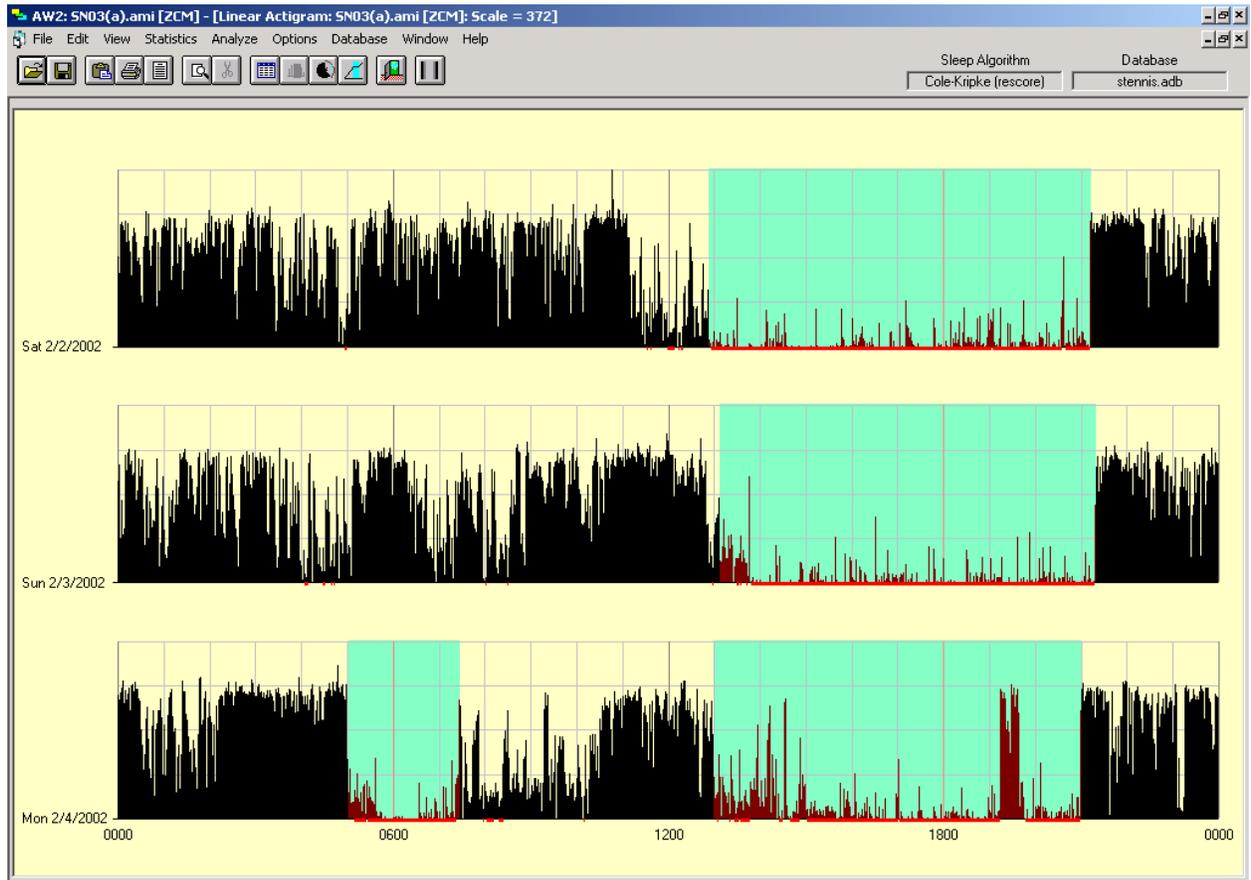
Figure 6. **ACTION-W VERSION 2**

Each row represents 24 hours of data. Each sleep episode period is highlighted in green. For this research, any period of greater than 20 minutes was considered to be sleep. Down periods were manually selected and compared to the participants' 72-hour log for accuracy and integrity of the data. Only those participants with at least 72 hours of data were used in the analysis. No consideration was given as to which day the data was collected because of the short collection period. The starting and ending points of the 72-hour periods varied for each participant. Statistical information from the down and up periods was used to calculate average daily sleep, average episode duration, total sleep, and total episodes. In the epoch-by-epoch folder, only date, time, and sleep score were marked to ensure readability in the FAST analytical tools. Files were saved as "epoch by epoch" (.epe) type.

4.   Fatigue Avoidance Scheduling Tools (FAST-TR)

Once the sleep and wake minutes were calculated in AW2, the data were imported into FAST (see Figure 7) to compute predicted effectiveness for each individual. Developed by NTI, Inc., FAST is a Windows-based tool that uses a quantitative model of the effects of sleep on cognitive effectiveness to illustrate predictions of individual cognitive effectiveness based upon actigraph-estimated sleep times.

Figure 7.   FAST-TR.

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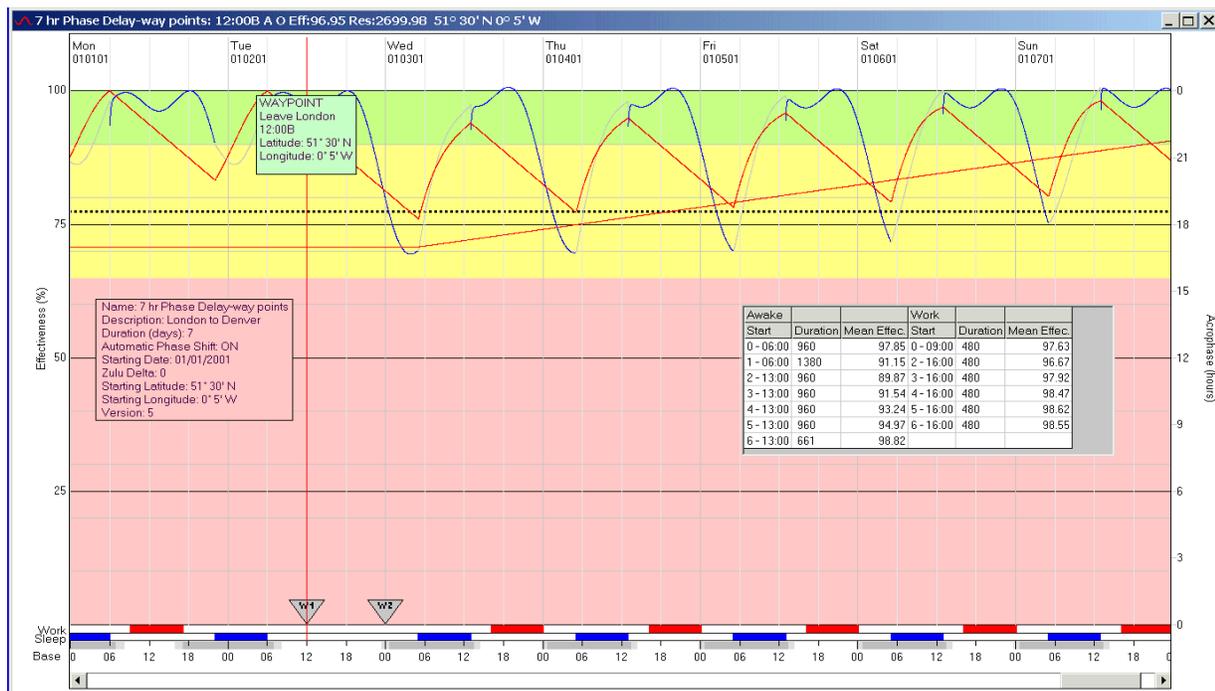
FAST (see Appendix M) is a fatigue assessment tool based on the SAFTE model discussed in greater detail in Chapter II. It does prospective forecasting of fatigue risk under any proposed work/rest schedule. Also, it helps to refine the predictions with information on actual sleep or special circumstances. The transportation version uses a two-step estimation process in which it estimates sleep pattern based on work schedule and performance effectiveness based on sleep pattern.

The red bands at the bottom of the graph represent work periods while blue bands depict sleep periods. The left vertical axis represents composite human performance index (also known as "throughput") with 100% as the highest effectiveness. The right vertical axis represents either acrophase or blood alcohol content equivalence. The green area on the chart represents 90% or more effectiveness. If the sleep reservoir is fully charged and the person continues to get a solid night's sleep, then their effectiveness during waking hours will remain in this green area. The yellow area (between 65% and 90%) represents the zone where precautions should be taken, while the red area (below 65%) corresponds to very low effectiveness. In this thesis, the area below the dotted line at 78% will be called the *danger zone*. This 78% cutoff is derived from Air Force guidelines (Hursh, 2001). Predicted performance is depicted by the oscillating blue line. The red oscillating line represents sleep reservoirs over a given period.

In addition to entering sleep and wake periods, participants' actigraph data were pre-conditioned (three day before and after) to depict as close to reality the amount of sleep in their sleep reservoirs. Sleep and wake periods were taken from AW2 statistical down and up results. Individuals' average sleep time and duration from AW2 were used in the pre-condition setup. Upon completion, information from "Tabular Data" and "Interval Statistic" were entered into an Excel file for further calculation of the working hour efficiency and the percent of time that the overall efficiency falls in the danger zone.

5.   **Thermometers and 72 Hours Log**

In addition to an actigraph, each participant was issued a personal digital thermometer (see Figure 8) to record oral temperature in Fahrenheit every three waking hours in order to approximate metabolic circadian rhythms. Also, participants were given

a 72-hour log (see Appendix J) to record time, sleepiness rating, oral temperature, and sleep quality. The log was compared to actual actigraphy data to ensure consistency and completeness.

Figure 8.   DIGITAL THERMOMETER

6.   Surveys

Prior to issuing the actigraph, logs, and digital thermometers, surveys were administered the participants for the purpose of gathering information such as demographic, sleep habits, and sleep concerns with the new work/sleep schedule. The thirteen demographic questions (see Appendix G) cover current duty assignment, age, rank, gender, nicotine use, caffeine consumption, and military and education experience. The eighteen STENNIS survey questions (see Appendix H) include the Stanford Sleepiness Scale for nocturnal sleepiness. The 12 Lark and Owl survey questions (see Appendix I) determine if the individual is a morning or night person. Using this questionnaire, individuals were categorized as a Lark, regular Robin, or Owl. A Lark is a morning person who gets up early and is normally more productive early in the morning. On the other hand, the Owl or night person is an individual who stays up late at night and hates getting up early in the morning. The regular Robin is one between the two extremes of Lark and Owl. Finally, the Profile of Mood States (POMS)is a measure of the mood states of an individual and is broken down into six affective states of Tension-Anxiety, Depression-Dejection, Anger-Hostility, Vigor-Activity, Fatigue-Inertia, and Confusion-Bewilderment (see Appendix K).

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C. SUBJECTS

Actigraphy, temperature, and survey data were collected from thirty-three enlisted crewmen assigned to USS JOHN C. STENNIS. The average sample age was 25.6 years with different military and educational backgrounds. The sample was made up of ship's force and air wings personnel from ten different Departments. The participants were all volunteers and were briefed on the confidentiality and purpose of the experiment. All participants signed the participant consent form (see Appendix D), minimum risk consent form (see Appendix E), and privacy act (see Appendix F) prior to filling out surveys and being assigned actigraphs and thermometers. They were given a choice to withdraw prior to and during the experiment without any consequences. Prior to collection of the log record and actigraph from a participant, they were again briefed on the confidentiality of the data and were provided with contact information in case questions arose after the researcher departed the ship.

D. DATA ENTRY AND CONDITIONING

Actigraphy, temperature, and survey data were imported into a master file in Microsoft Excel 2000 spreadsheet and SPSS 2000. Each row represented the responses of one subject. Columns represented survey questions, average episode and sleep hours, and effectiveness scores. Survey questions items that have no response are left blank as required in SPSS 2000. Also, results from AW2 and FAST-TR were imported into the Excel master file. Graphs and tables were generated from SPSS 2000, PowerPoint, and Excel. Most of the analysis was done in SPSS 2000, with the exception of regression models, which were done in Excel. Analyses of temperature, Lark and Owl survey, and POMS were considered outside the scope of the current thesis and have been left for future analysis.

Of the thirty-three participants (27 males and 6 females) who volunteered for the study, twenty-eight data sets (corresponding to 22 males and 6 females) were used in the initial descriptive analysis presented in Chapter 4. Data from five participants were separated from the initial analysis and ultimately excluded because it was determined that

those individuals were sleeping at night and working days. Furthermore, a decision was made by the researcher to exclude four more data sets because they contained less than 72 hours of actigraphy recording. A comparison was made between the 28 subject versus 24 subject (19 males and 5 females) data sets to see whether excluding the four sets of data made any substantive differences in the results of the study. The comparison is presented in Chapter 4.

IV.   STATISTICAL RESULTS

A.   CHAPTER OVERVIEW

This descriptive analysis is limited to 28 participants who sleep only during the daytime (1000-1800) to allow concentration on those individuals working at night in the inverted sleep/work schedule.   Section B of this chapter outlines selected survey questions and actigraphy data used in the analyses of the study.   Section C provides a descriptive analysis of the sample survey questions for those 28 participants who are shown (by both survey and actigraphy data) as working at night.   Section D contains a detailed descriptive and statistical analysis of sample actigraphy data for those participants who had completed 72 hours of actigraphy recording.   Section E contains group comparisons, while Section F provides the results of a regression analysis of one of these outcomes (average daily sleep) that describe factors that appear to influence sleep patterns in this study.

B.   SAMPLE SELECTION

Of the 32 questions contained on the demographic and STENNIS surveys, only a few are addressed in this study.   Table 1 lists these specific questions with their means, standard deviations, and medians. Questions such as height, weight, PRT scores, medications, military experiences, and others not listed in Table 1 are considered outside the scope of the current thesis and have been left for future analysis.

Selected Survey Questions	Mean	Standard Deviation	Median
What is the average length of your watch? (in hours)	8.86	3.37	10.50
How many days have you been on your current watch rotation?	53.71	29.67	53.50
In the past four weeks, have you been able to work out? (Circle one): 0–1 times per week 2-3 times per week 4 or more times per week	1.93	.81	2.00
Have you been using MORE tobacco products since going on this work/sleep schedule? (Circle one): Less Same More	1.67	.65	2.00
Have you been drinking MORE caffeinated beverages since going on this work/sleep schedule? (Circle one): Less Same More	2.04	.64	2.00
Did you ever completely adjust? Yes No	.54	.51	1.00
How long did it take for you to adjust? _____ Days	16.50	12.97	10.00

Table 1.   SELECTED SURVEY QUESTIONS

C.   DESCRIPTIVE ANALYSIS OF SURVEY DATA

Descriptive statistics are used to depict information about the distribution of survey questions for the 28 night-shift participants, with an emphasis on examining potential differences among male/female, topside/belowdecks conditions, and adjusted/non-adjusted individuals. Histograms are used to depict empirical distributions for continuous data, such as age and the number of days on current watch. Bar charts are used to create visual displays of categorical data, such as gender, and tables are used as a descriptive tool to depict other demographic and survey information. Independent sample

two-tailed t-tests (at significance level α=0.05) are performed to determine if answers to the survey questions differ significantly by group.

1.   Age

Figure 9 shows the distribution of ages of the participants. Since there were so few females (6 in total), their ages are indicated by segmenting the appropriate bins in the histogram, rather than creating separate histograms by gender. The mean response fell in the "25-26" age category. Furthermore, 19/28 of the participants (64% of men and 83% of women) reported they were less than 24 years old. The difference in age between males and females was not statistically significant (p-value = 0.32).
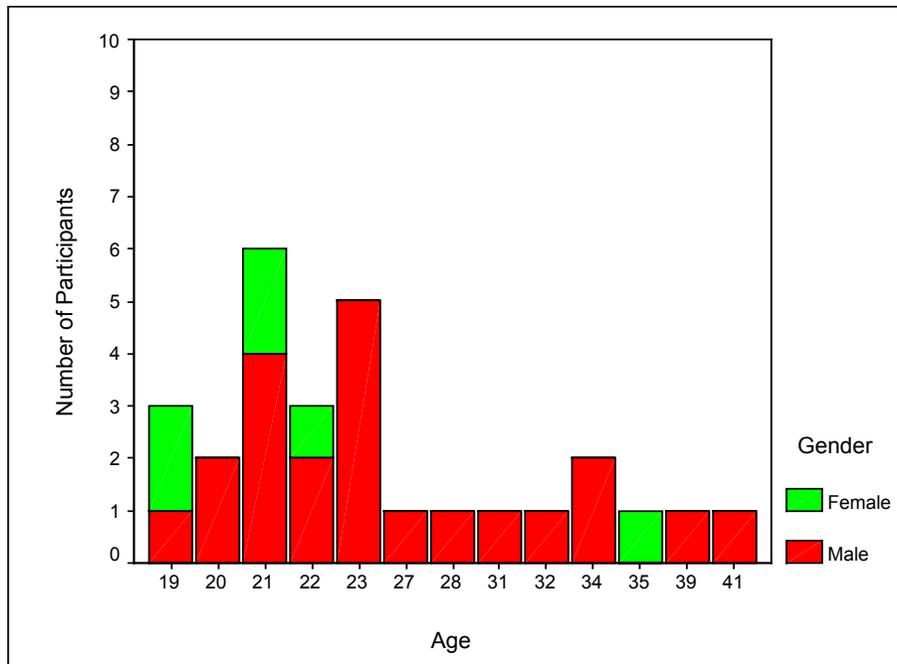
Figure 9.   HISTOGRAM OF AGE

2. Gender

22/28 (78%) of the participants surveyed were males. Potential gender differences in survey responses and actigraphy data will be described in Section E.

3. Average Watch Length

The average reported watch length across all 28 participants was 8.9 hours. Males reported an average of 8.64 hours for watch length while females reported an average of 9.67 hours. The difference in watch length between males and females was not statistically significant (p-value = 0.52). Half the participants reported their watch length was 12 hours. One caveat is that these participants may have been confused and reported watch length as working hours vice actual hours on watch, since they indicated their watch rotations were "12 on, 12 off." Figure 10 depicts the average watch length for the 28 participants by gender.
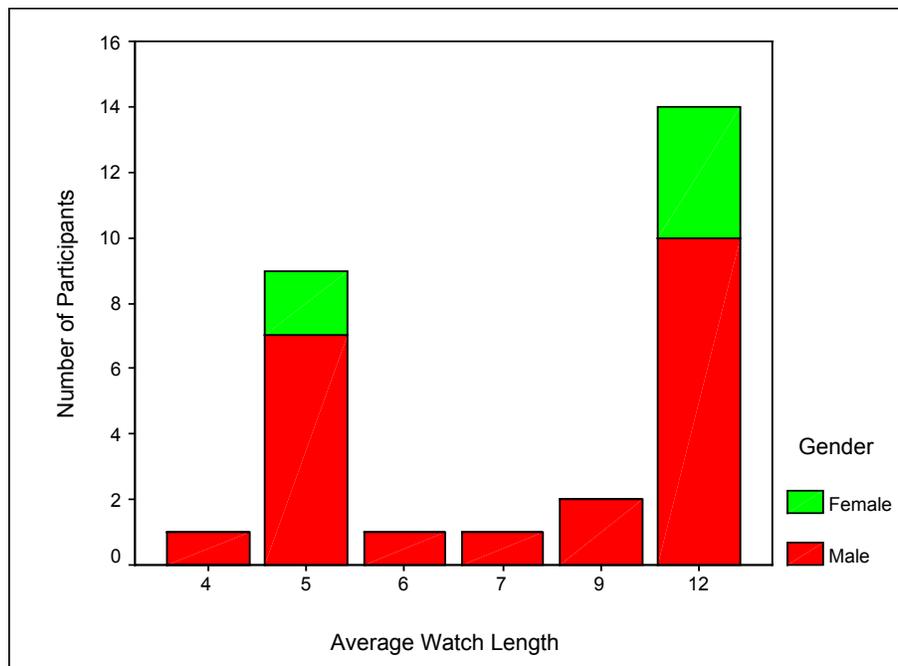
Figure 10.   HISTOGRAM OF AVERAGE WATCH LENGTH

### 4.	Days on Current Watch Rotation

The participants averaged 53.7 days on their current watch rotation as illustrated in Figure 11. 21.6% of the participants reported they had spent 40 or fewer days on their current schedule. Males averaged 55.55 days, compared to 47.00 days on average for females. The 8.55-day difference in days on current watch rotation between males and females was not statistically significant (p-value = 0.54).
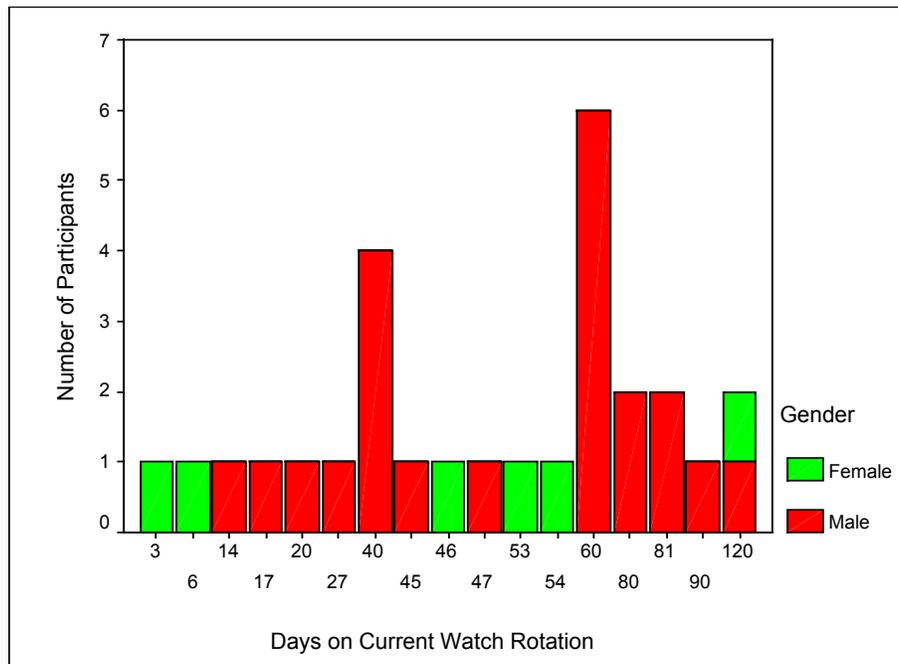
**Figure 11.	HISTOGRAM OF DAYS ON CURRENT WATCH ROTATION**

### 5.	Adjustment

One of the most interesting statistics presented in Table 2 is the percentage of participants that reported that they never completely adjusted to the reversed schedule. 46.4% of all the participants reported that they were not fully adjusted, even though over thirty days had passed since the USS STENNIS switched to the night schedule. Females appeared to have a lower rate of adjustment (33.3%) than males (59.1%). The difference

in adjustment rates between males and females was not statistically significant. (p-value = 0.28). However, the power of this test is low due to the small sample size for females.

| | | | Gender | | |
			1 Male	2 Female	Total
Have you ever completely adjusted? No		Count	9	4	13
		% within Have you ever completely adjusted?	69.2%	30.8%	100.0%
		% within Gender	40.9%	66.7%	46.4%
		% of Total	32.1%	14.3%	46.4%
	Yes	Count	13	2	15
		% within Have you ever completely adjusted?	86.7%	13.3%	100.0%
		% within Gender	59.1%	33.3%	53.6%
		% of Total	46.4%	7.1%	53.6%
Total		Count	22	6	28
		% within Have you ever completely adjusted?	78.6%	21.4%	100.0%
		% within Gender	100.0%	100.0%	100.0%
		% of Total	78.6%	21.4%	100.0%

Table 2.   SELF-REPORTED ADJUSTMENT

6.   Topside/Belowdecks

Figure 12 shows the topside/belowdecks distribution by gender. 12 of the 28 participants were classified as working topside. Of the 12 working topside, 75% were male. The females were equally split across work assignments with half working topside and half working belowdecks.   The difference in work conditions between males and females was not statistically significant (p-value = 0.70).
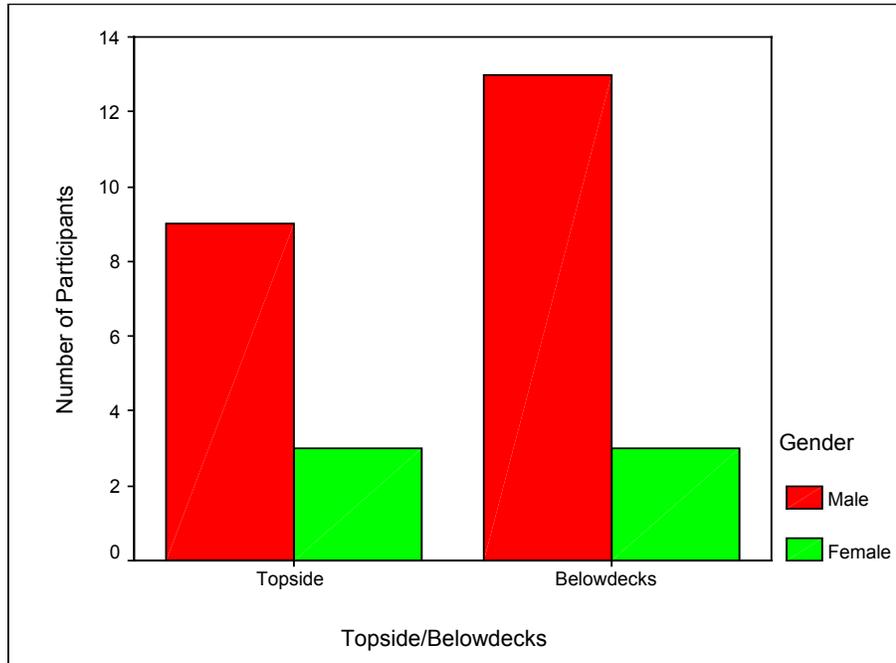
Figure 12. **BAR CHART OF TOPSIDE/BELOWDECKS AND GENDER**

D. DESCRIPTIVE ANALYSIS OF ACTIGRAPHY DATA

A descriptive analysis was performed on actigraphy data for both the 24 participant and 28 participant data sets. We compared average daily and sleep episode by gender, adjustment, and work conditions by use of bar charts. Independent sample two-tailed t-tests (at significance level $\alpha=0.05$) were performed to determine if their means differed significantly from each other.

1. Average Daily Sleep for 28 Participants

Males and females averaged 6.37 hours and 5.94 hours of sleep per day, respectively. This 25.8-minute difference was not statistically significant (p-value= 0.81). Figure 13 provides more information about the average daily sleep patterns. The medians for males and females were 6.19 and 6.57 hours, respectively. The ranges for both genders, while similar, were quite large: a 7.10-hour difference for males and a 6.25-hour difference for females. The high variability, along with a small sample size for females, makes it difficult to detect small or moderate differences in the means.
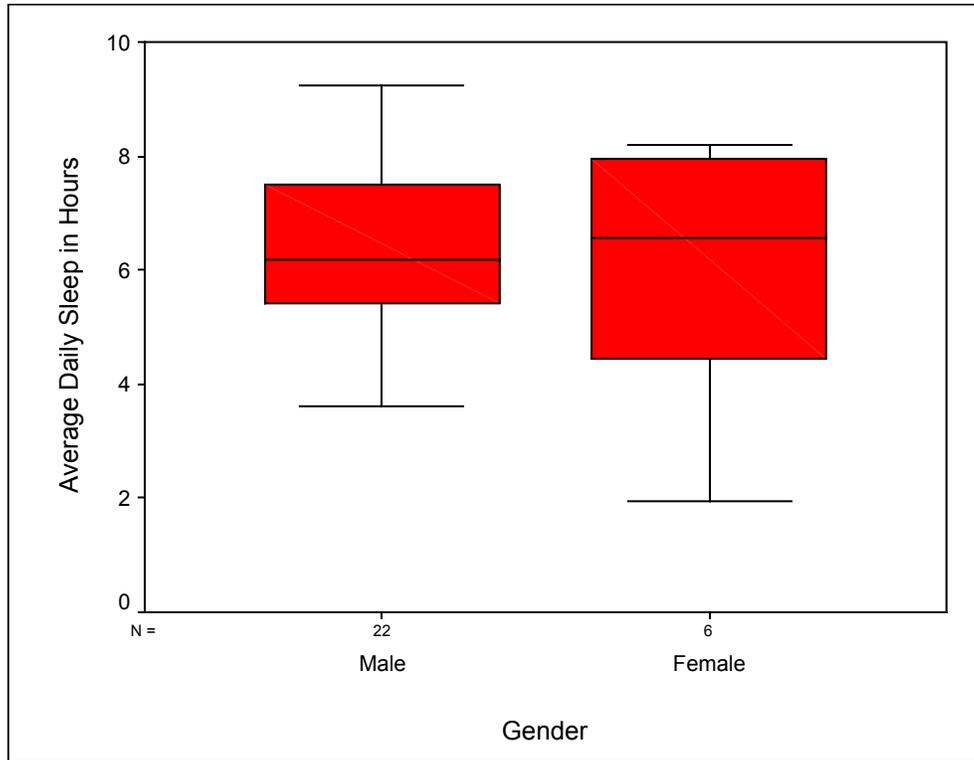
Figure 13.   BOX PLOT OF AVERAGE DAILY SLEEP BY GENDER

Similarly, Figure 14 illustrates the average daily sleep patterns by self-reported adjusted/non-adjusted participants. It is interesting to see that the medians and ranges were quite similar, which does not agree with the sleep research described in Chapter 3. This could be a result of cognitive dissonance where participants convinced themselves that they had adjusted though in reality they had not. Furthermore, the difference could be from a participant's interpretation of the question—"Ever adjusted" does not necessarily mean "currently adjusted." The means were not statistically different: 6.19 hours for non-adjusted and 6.36 hours for adjusted individuals (p-value= 0.81). In summary, these results indicate that factors other than average daily sleep may have affected participants' perceptions of their ability to adjust to the inverted work schedule.
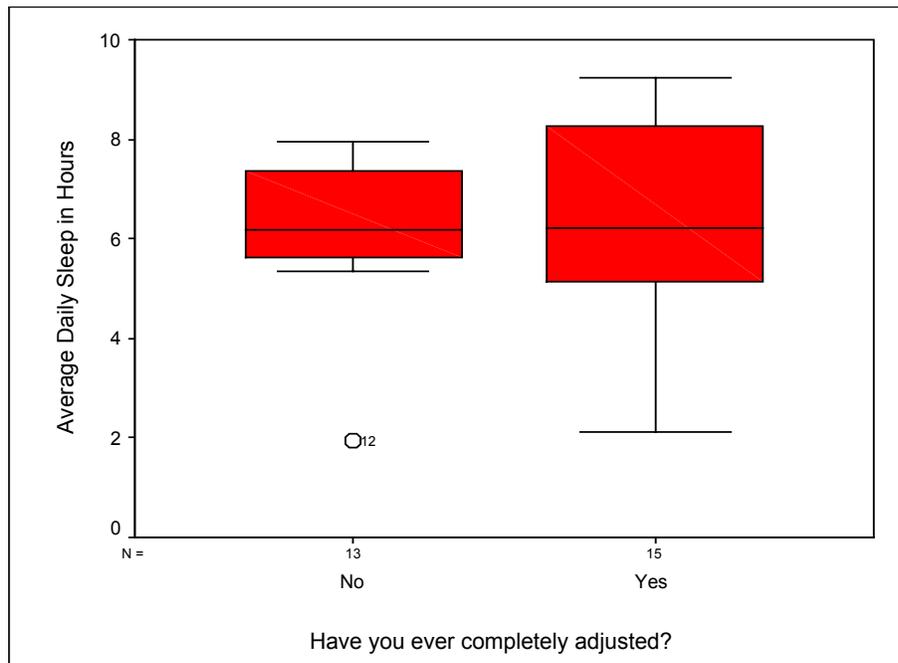
Figure 14.   BOX PLOT OF AVERAGE DAILY SLEEP BY ADJUSTMENT

One of the most interesting findings of our exploratory data analysis is presented in Figure 15, which displays the difference in average daily sleep for topside and belowdecks conditions. Individuals working belowdecks averaged 7.45 hours of sleep.

On the other hand, those working topside averaged a remarkably low 4.72 hours of sleep per day. This difference was statistically significant (p-value = 0.00). The medians for topside and belowdecks conditions were 5.32 and 7.47 hours, respectively. The ranges were 4.39 hours for topside and 3.60 for belowdecks. It is also interesting to see that the maximum average daily sleep hours for topside (6.33 hours) was very close to the first quartile of sleep hours for belowdecks (6.48 hours). This means that 75% of those working belowdecks received more sleep, on average, than any of those working topside.
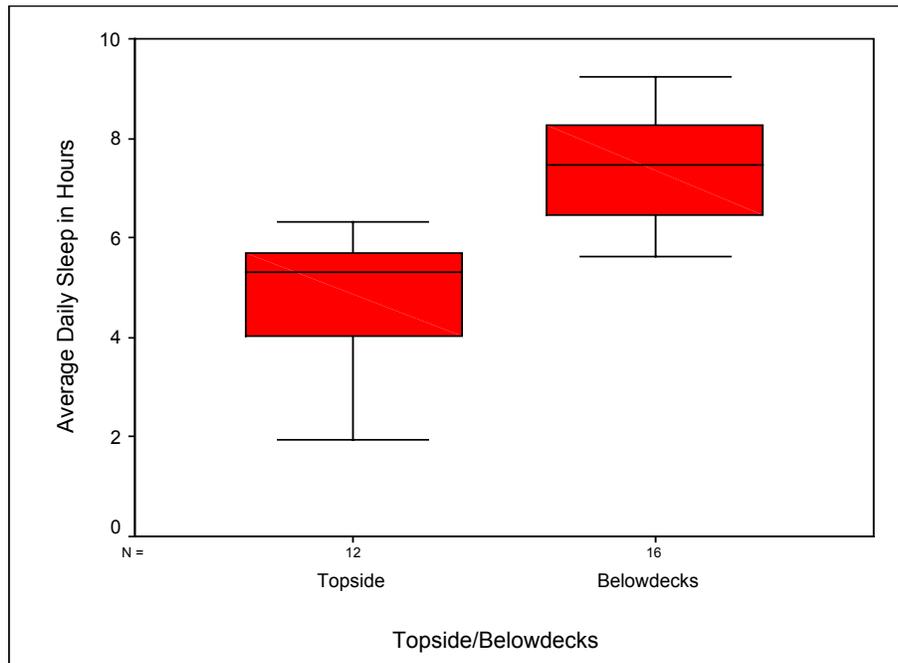
Figure 15. **BOX PLOT OF AVERAGE DAILY SLEEP BY TOPSIDE/BELOWDECKS**

2. Average Daily Sleep for 24 Participants

We now describe the data for only those individuals for which a full 72 hours of actigraph data were available. Box plots of the daily sleep for males and females are illustrated in Figure 16, and differ only slightly from their counterparts for the 28 individuals (Figure 13). Males and females averaged 6.15 hours and 6.24 hours of sleep per day, respectively. This 5.4-minute difference was not statistically significant (p-value = 0.92). The medians for males and females were 6.18 and 7.36 hours, respectively.

The ranges for both genders, while similar, were quite large: a 6.65-hour difference for males and a 6.25-hour difference for females.
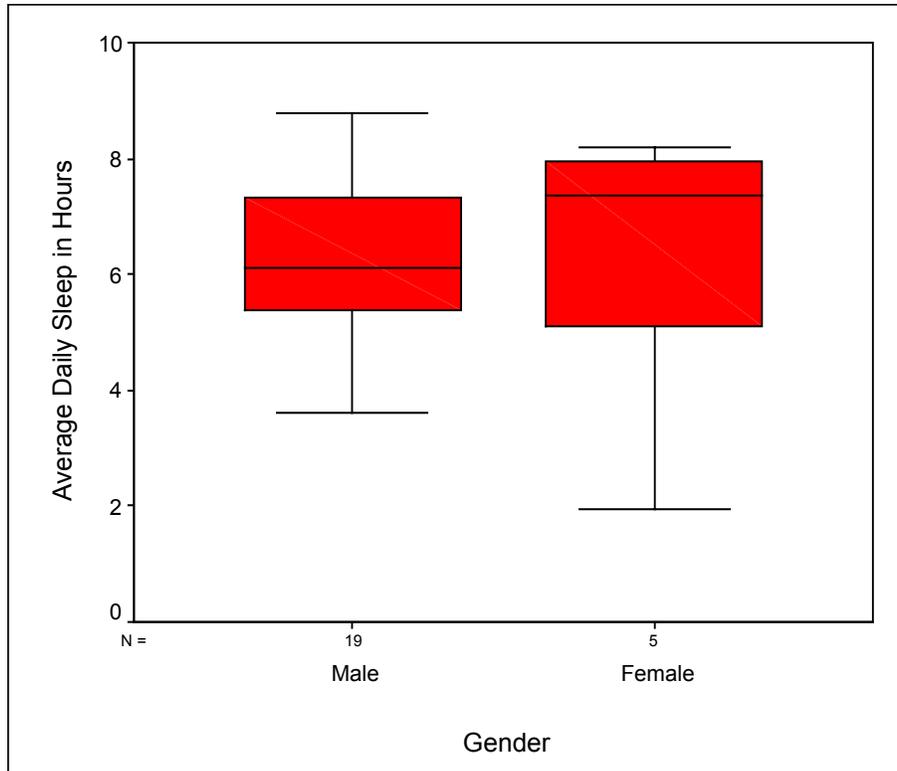
Figure 16.   **BOX PLOT OF AVERAGE DAILY SLEEP BY GENDER**

Figure 17 illustrates the average daily sleep patterns for self-reported adjusted/non-adjusted participants. Once again, these results are qualitatively similar to the data for all 28 participants (Figure 14). The means were not statistically different: 6.24 hours for non-adjusted and 6.10 hours for adjusted individuals (p-value= 0.85). The medians were also similar, and the ranges were once again close to each other: 6.00 hours for adjusted and 6.65 hours for non-adjusted.
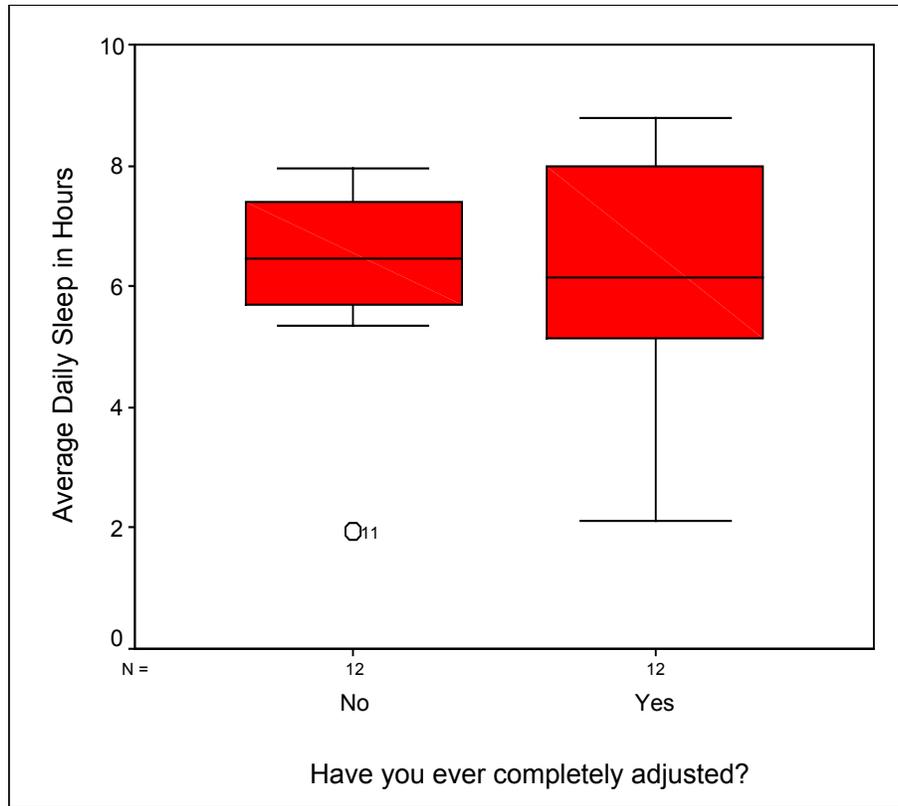
Figure 17.   **BOX PLOT OF AVERAGE DAILY SLEEP BY ADJUSTMENT**

One of the most interesting findings presented in Figure 18 is the difference in average daily sleep for topside and belowdecks conditions. Those working belowdecks averaged 7.37 hours of sleep. On the other hand, those working topside averaged a remarkably low 4.74 hours of sleep per day. This 2.63-hour difference was highly significant (p-value=0.00). The medians for topside and belowdecks conditions were 5.34 and 7.38 hours, respectively. It is interesting to see that the ranges were quite different: 4.39 hours topside and 2.65 belowdecks. For these 24 participants, the maximum average daily sleep for those working topside (6.33 hours) was very close to the minimum average daily sleep for those working belowdecks (6.12 hours).
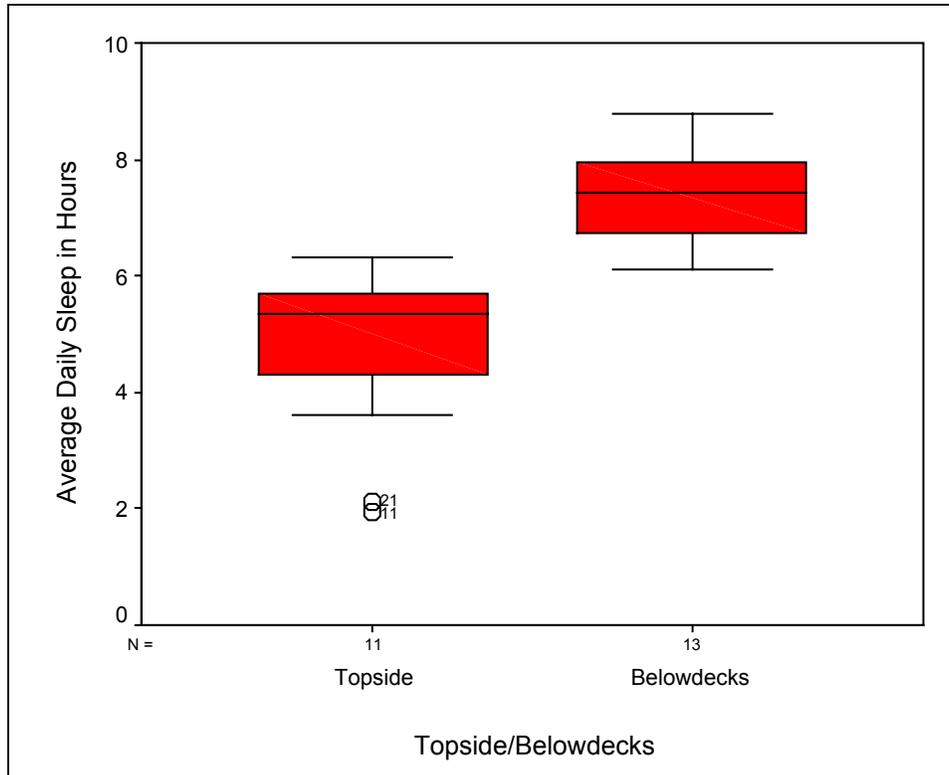
Figure 18.   **BOX PLOT OF AVERAGE DAILY SLEEP BY**
TOPSIDE/BELOWDECKS

3.   Average Sleep Episode Duration for 28 Participants

The average sleep episode duration (i.e., the average amount of sleep per episode) for males and females is illustrated in Figure 19. Males and females averaged 5.46 hours and 5.78 hours of sleep per episode, respectively. This 19.2-minute difference was not statistically significant (p-value = 0.63). The medians for males and females were 5.01 and 4.26 hours, respectively. The ranges for both genders were quite large (8.42 hours for males and 6.54 hours for females).
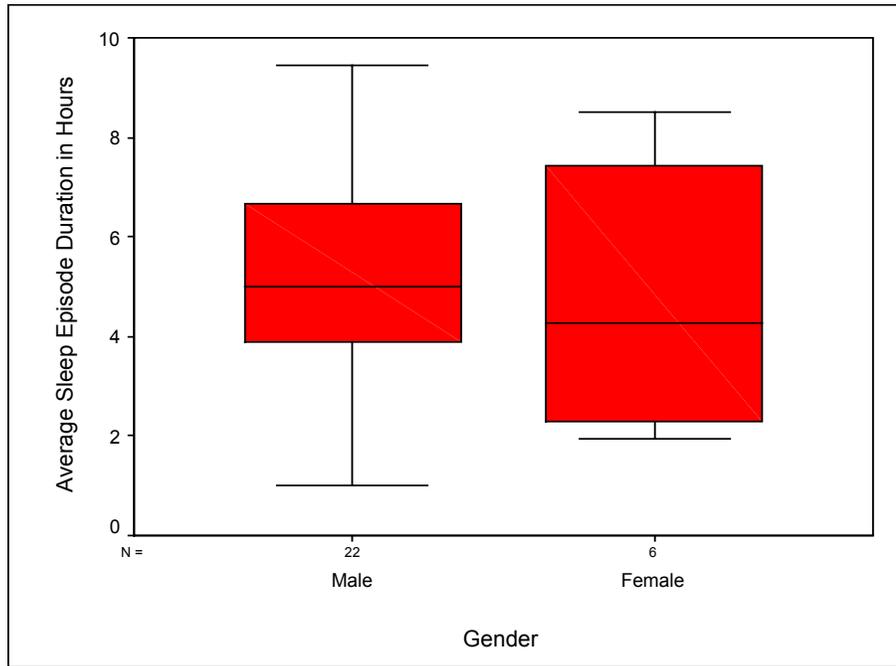
Figure 19.   BOX PLOT OF AVERAGE SLEEP EPISODE DURATION BY GENDER

Figure 20 illustrates the average sleep episode durations for self-reported adjusted/non-adjusted participants. The medians for males and females were 6.39 and 4.76 hours, respectively. As in Figure 19 the ranges were large: 6.69 hours for adjusted and 8.42 hours for non-adjusted individuals. The means were not statistically significant: 5.68 hours for non-adjusted and 5.00 hours for adjusted individuals (p-value= 0.45).
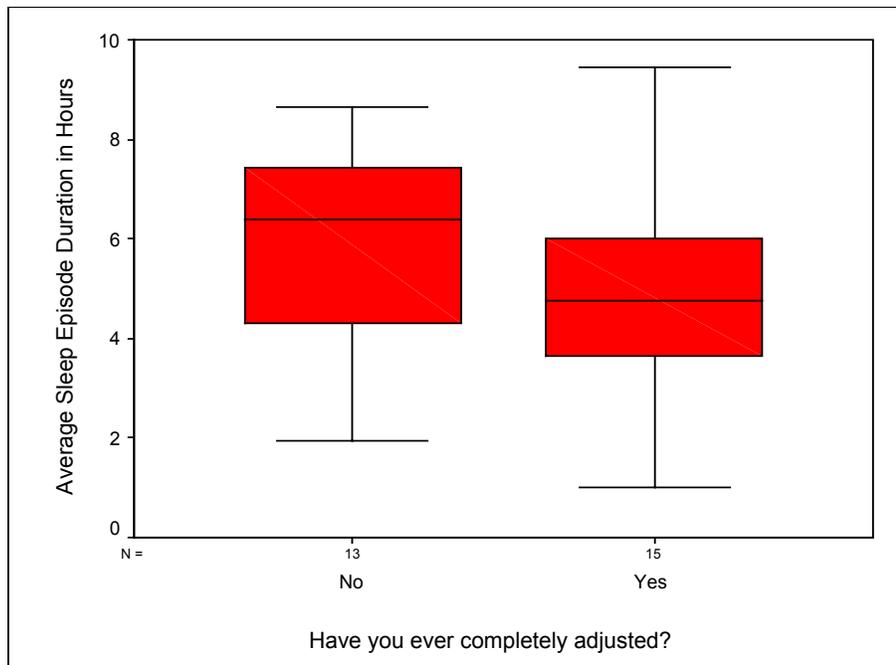
Figure 20.   **BOX PLOT OF AVERAGE SLEEP EPISODE DURATION BY ADJUSTMENT**

One of the most interesting findings presented in Figure 21 is the difference in average sleep episode duration for topside and belowdecks conditions. Those working belowdecks averaged 6.83 hours of sleep per episode. Conversely, those working topside averaged only 3.29 hours of sleep per episode. This 3.54-hour difference was statistically significant (p-value=0.00). The medians for topside and belowdecks conditions were 3.40 and 6.60 hours, respectively. It is interesting to see that the ranges were quite different: 3.82 hours topside and 5.67 belowdecks. It is also interesting to see that the

maximum average daily sleep hours for topside (4.83 hours) was very close to the minimum sleep hours for belowdecks (3.76 hours). The topside worker with the longest average sleep episode duration got only 1.07 hours more sleep than the belowdecks worker with the shortest average sleep episode duration.
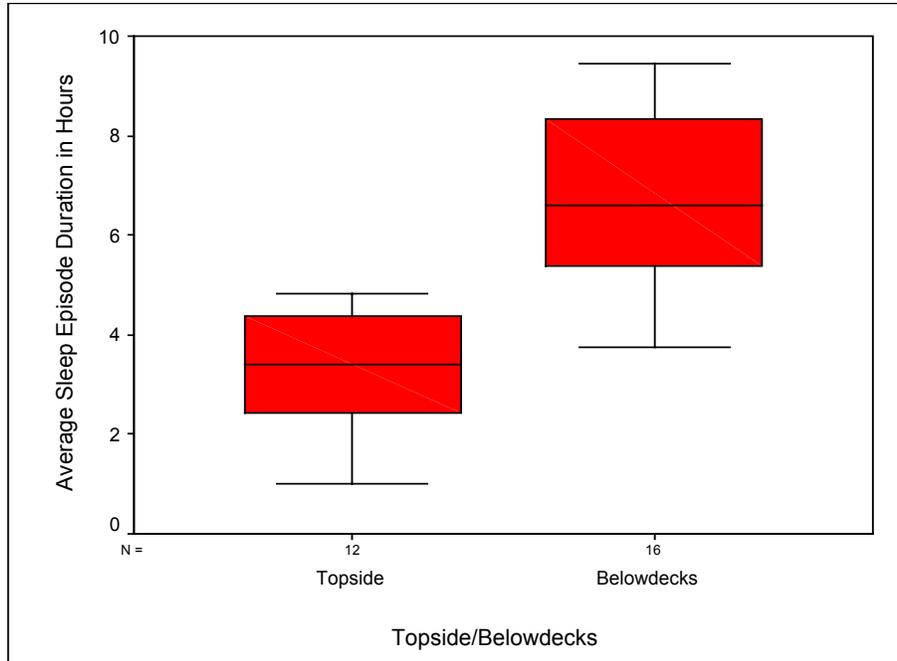
Figure 21.   **BOX PLOT OF AVERAGE SLEEP EPISODE DURATIONS BY TOPSIDE/BELOWDECKS**

4.   Average Sleep Episode Duration for 24 Participants

We now describe the data for only those individuals for which a full 72 hours of actigraph data were available. Males and females averaged 5.37 hours and 5.28 hours of sleep per episode, respectively.   This 5.4-minute difference was not statistically significant (p-value = 0.94). Figure 22 provides more information about the average sleep episode durations. The medians for males and females were 4.83 and 5.27 hours,

respectively. The ranges for both genders were quite large (8.42 hours for males and 6.54 hours for females).
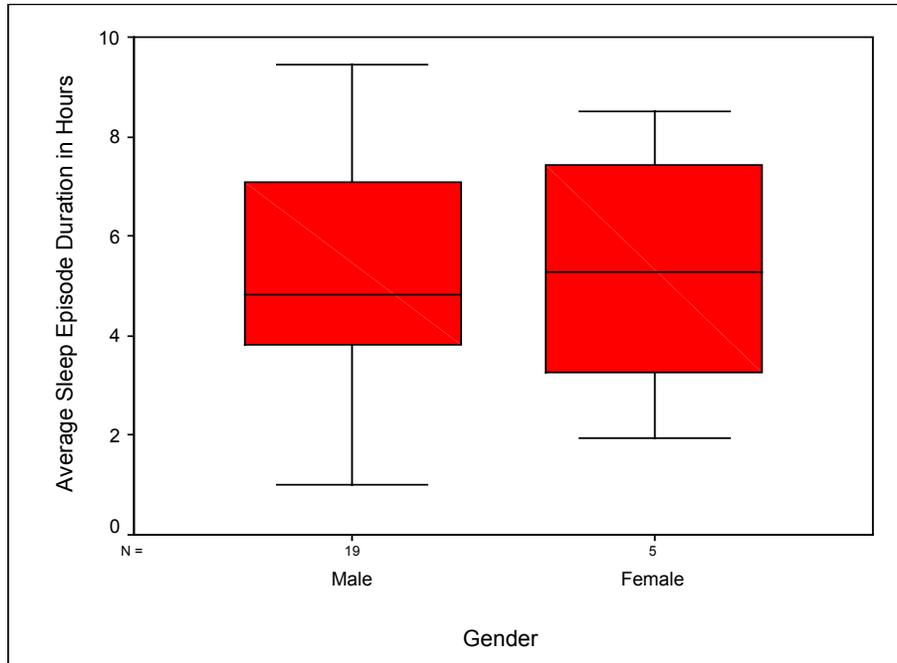
Figure 22. **BOX PLOT OF AVERAGE SLEEP EPISODE DURATION BY GENDER**

Similarly, Figure 23 illustrates the average sleep episode duration by self-reported adjusted/non-adjusted personnel. The medians for males and females were 5.83 and 4.60 hours, respectively. The means were not statistically different: 5.59 hours for non-adjusted and 5.11 hours for adjusted individuals (p-value= 0.63). The ranges were large for both groups: 6.69 hours for adjusted and 8.42 hours for non-adjusted.
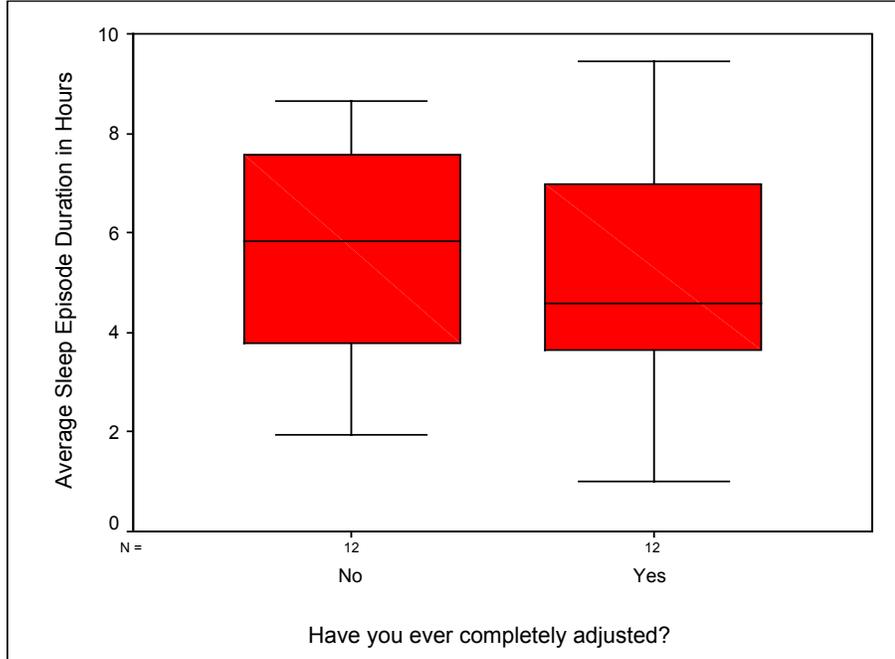
Figure 23. **BOX PLOT OF AVERAGE SLEEP EPISODE DURATION BY ADJUSTMENT**

Once again, the difference in average sleep episode for topside and belowdecks conditions is striking (Figure 24). Those working belowdecks averaged 7.02 hours of sleep per episode. Conversely, those working topside averaged only about half this amount: 3.38 hours of sleep per episode. This 3.64-hour difference was statistically significant (p-value = 0.00). The medians for topside and belowdecks conditions were 3.55 and 7.43 hours, respectively. The ranges were the same as in Figure 21. As before, the longest average sleep episode duration among the topside workers was only 1.07 hours longer than the smallest average sleep episode duration among belowdecks workers.
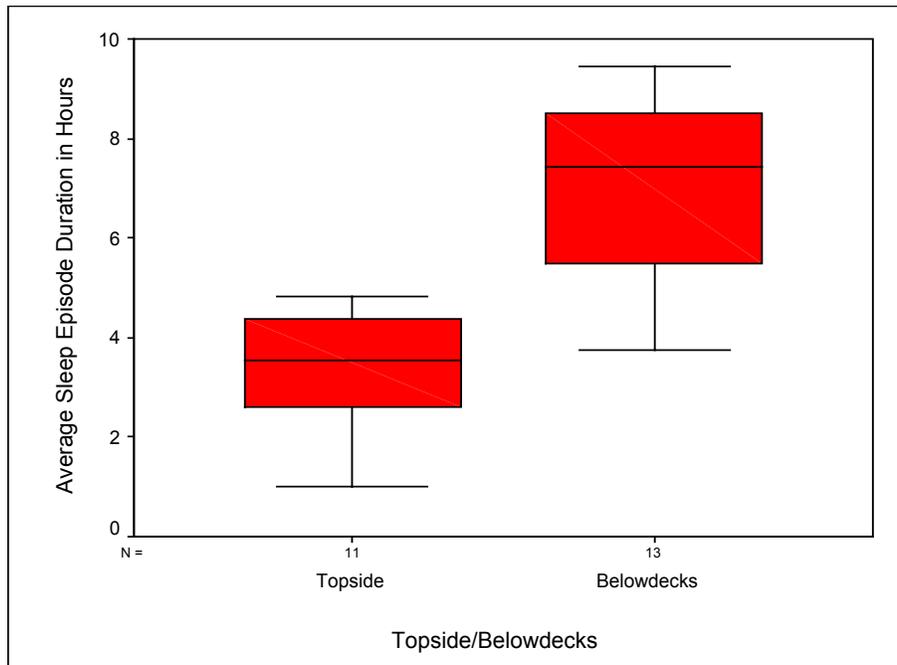
Figure 24. **BOX PLOT OF AVERAGE SLEEP EPISODE DURATION BY TOPSIDE/BELOWDECKS**

E. COMPARISIONS BY GROUP

Based on the descriptive results, we decided to perform a more detailed analysis by splitting the data across three dimensions: gender, self-reported adjustment, and topside versus belowdecks conditions. Independent sample two-tailed t-tests (at significance level α=0.05) were performed to determine if answers to the survey questions differed significantly by group. For each pair-group, a group statistic table was generated with the mean, standard deviation, and standard error of mean. In addition, an independent sample t-test table was generated to test for the equality of the means.

1. Gender

Table 3 provides the summary statistics by gender. Male and female responses to survey questions, and results calculated from actigraphy data, were compared. Although gender did not appear to be a significant factor in the exploratory analysis earlier in this Chapter, Table 3 allows comparisons for other questions. Table 4 shows the results of t-

tests for equality of means for males and females. The only statistically significant comparison was that caffeine consumption differed (p-value=0.039): on average, males reported less caffeine usage than females. Since the responses to this question were categorical, we also provided a crosstabulation in Table 5. The chi-squared statistic associated with this test had a p-value 0.098.

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Days on current watch rotation	1 Male	19	56.89	26.04	5.97
	2 Female	5	45.60	47.36	21.18
Average Watch Length	1 Male	19	8.26	3.43	.79
	2 Female	5	9.20	3.83	1.71
Topside/Belowdecks	1 Male	19	.47	.51	.12
	2 Female	5	.60	.55	.24
Have you ever completely adjusted?	1 Male	19	.58	.51	.12
	2 Female	5	.20	.45	.20
Average Sleep Episode Duration in Hours	1 Male	19	5.5516	2.3515	.5395
	2 Female	5	5.2780	2.7448	1.2275
Average Daily Sleep in Hours	1 Male	19	6.1453	1.5934	.3655
	2 Female	5	6.2420	2.5811	1.1543
Total Number of Sleep Episodes	1 Male	19	5.11	2.02	.46
	2 Female	5	5.20	2.28	1.02
Percent of Time Spent in Danger Zone	1 Male	19	.5084	.2268	5.202E-02
	2 Female	5	.4820	.2767	.1237
Percent of Effectiveness During Waking Hours	1 Male	19	.7763	8.139E-02	1.867E-02
	2 Female	5	.7700	9.513E-02	4.254E-02
How often do you work out per week?	1 Male	19	1.79	.79	.18
	2 Female	5	1.80	.84	.37
How much tobacco do you use?	1 Male	11	1.64	.67	.20
	2 Female	1	2.00	.	.
How much caffeine do you use?	1 Male	19	1.89	.66	.15
	2 Female	5	2.60	.55	.24
How long did it take for you to adjust?	1 Male	19	15.53	12.89	2.96
	2 Female	5	24.40	12.52	5.60

Table 3.   SUMMARY STATISTICS BY GENDER

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		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Days on current watch rotation	Equal variances assumed	1.825	.190	.724	22	.477	11.29	15.59	-21.05	43.64
	Equal variances not assumed			.513	4.655	.631	11.29	22.01	-46.56	69.15
Average Watch Length	Equal variances assumed	.097	.758	-.532	22	.600	-.94	1.76	-4.59	2.72
	Equal variances not assumed			-.497	5.804	.638	-.94	1.89	-5.59	3.72
Topside/Belowdecks	Equal variances assumed	.494	.490	-.484	22	.633	-.13	.26	-.67	.42
	Equal variances not assumed			-.465	5.989	.658	-.13	.27	-.79	.54
Have you ever completely adjusted?	Equal variances assumed	6.058	.022	1.517	22	.143	.38	.25	-.14	.90
	Equal variances not assumed			1.638	6.989	.146	.38	.23	-.17	.93
Average Sleep Episode Duration in Hours	Equal variances assumed	.108	.745	.224	22	.825	.2736	1.2203	-2.2571	2.8042
	Equal variances not assumed			.204	5.648	.845	.2736	1.3408	-3.0576	3.6048
Average Daily Sleep in Hours	Equal variances assumed	1.686	.208	-.106	22	.916	-9.674E-02	.9115	-1.9870	1.7936
	Equal variances not assumed			-.080	4.832	.940	-9.674E-02	1.2108	-3.2421	3.0486
Total Number of Sleep Episodes	Equal variances assumed	.001	.978	-.091	22	.928	-9.47E-02	1.04	-2.26	2.07
	Equal variances not assumed			-.085	5.777	.935	-9.47E-02	1.12	-2.86	2.67
Percent of Time Spent in Danger Zone	Equal variances assumed	.021	.887	.222	22	.826	2.642E-02	.1189	-.2202	.2731
	Equal variances not assumed			.197	5.501	.851	2.642E-02	.1342	-.3094	.3623
Percent of Effectiveness During Waking Hours	Equal variances assumed	.199	.660	.149	22	.883	6.316E-03	4.225E-02	-8.13E-02	9.393E-02
	Equal variances not assumed			.136	5.643	.897	6.316E-03	4.646E-02	-.1091	.1218
How often do you work out per week?	Equal variances assumed	.015	.903	-.026	22	.979	-1.05E-02	.40	-.84	.82
	Equal variances not assumed			-.025	6.009	.981	-1.05E-02	.42	-1.03	1.01
How much tobacco do you use?	Equal variances assumed	.	.	-.516	10	.617	-.36	.70	-1.93	1.21
	Equal variances not assumed			.	.	.	-.36	.	.	.
How much caffeine do you use?	Equal variances assumed	.002	.965	-2.195	22	.039	-.71	.32	-1.37	-3.89E-02
	Equal variances not assumed			-2.451	7.377	.042	-.71	.29	-1.38	-3.19E-02
How long did it take for you to adjust?	Equal variances assumed	2.316	.142	-1.377	22	.182	-8.87	6.44	-22.24	4.49
	Equal variances not assumed			-1.401	6.429	.207	-8.87	6.33	-24.12	6.37

Table 4.   INDEPENDENT SAMPLE T-TEST RESULTS FOR COMPARING GENDER DIFFERENCES

			How much caffeine do you use?			
			Less	Same	More	Total
Gender	Male	Observed	5	11	3	19
		Expected	4.0	10.3	4.8	19.0
	Female	Observed	0	2	3	5
		Expected	1.0	2.7	1.3	5.0
Total		Observed	5	13	6	24
		Expected	5.0	13.0	6.0	24.0

Table 5.   CROSSTABULATION OF CAFFEINE CONSUMPTION AND GENDER

2.   Adjusted Versus Non-adjusted Participants

Table 6 provides the summary statistics for the adjusted/non-adjusted participants. The question regarding the length of time needed to adjust is not shown, since data were available only for the adjusted group. Note that non-adjusted personnel required more than 30 days to adjust, since it had been at least that long since the ship shifted to a night schedule. However, many adjusted personnel reported they needed 30 or more days to adjust. Table 7 shows the t-tests for equality of means between adjusted and non-adjusted personnel. There were no significant differences in any of the comparisons.

	Have you ever completely adjusted?	N	Mean	Std. Deviation	Std. Error Mean
Days on current watch rotation	0 No	12	54.92	28.03	8.09
	1 Yes	12	54.17	34.43	9.94
Average Watch Length	0 No	12	8.58	3.58	1.03
	1 Yes	12	8.33	3.47	1.00
Topside/Belowdecks	0 No	12	.50	.52	.15
	1 Yes	12	.50	.52	.15
Average Sleep Episode Duration in Hours	0 No	12	5.5942	2.2371	.6458
	1 Yes	12	5.3950	2.6055	.7522
Average Daily Sleep in Hours	0 No	12	6.2358	1.6122	.4654
	1 Yes	12	6.0950	1.9926	.5752
Total Number of Sleep Episodes	0 No	12	4.75	1.76	.51
	1 Yes	12	5.50	2.28	.66
Percent of Time Spent in Danger Zone	0 No	12	.5075	.2384	6.883E-02
	1 Yes	12	.4983	.2352	6.791E-02
Percent of Effectiveness During Waking Hours	0 No	12	.7742	6.788E-02	1.960E-02
	1 Yes	12	.7758	9.765E-02	2.819E-02
How often do you work out per week?	0 No	12	1.92	.79	.23
	1 Yes	12	1.67	.78	.22
How much tobacco do you use?	0 No	4	1.50	.58	.29
	1 Yes	8	1.75	.71	.25
How much caffeine do you use?	0 No	12	2.08	.79	.23
	1 Yes	12	2.00	.60	.17
Gender	0 No	12	1.33	.49	.14
	1 Yes	12	1.08	.29	8.33E-02

Table 6.   SUMMARY STATISTICS BY ADJUSTMENT

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
| | | | | | | | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
		F	Sig.	t	df	Sig. (2-tailed)			Lower	Upper
Days on current watch rotation	Equal variances assumed	.210	.652	.059	22	.954	.75	12.82	-25.83	27.33
	Equal variances not assumed			.059	21.130	.954	.75	12.82	-25.89	27.39
Average Watch Length	Equal variances assumed	.627	.437	.174	22	.864	.25	1.44	-2.74	3.24
	Equal variances not assumed			.174	21.980	.864	.25	1.44	-2.74	3.24
Topside/Belowdecks	Equal variances assumed	.	.	.000	22	1.000	.00	.21	-.44	.44
	Equal variances not assumed			.000	22.000	1.000	.00	.21	-.44	.44
Average Sleep Episode Duration in Hours	Equal variances assumed	.120	.732	.201	22	.843	.1992	.9914	-1.8568	2.2551
	Equal variances not assumed			.201	21.508	.843	.1992	.9914	-1.8595	2.2578
Average Daily Sleep in Hours	Equal variances assumed	.611	.443	.190	22	.851	.1408	.7399	-1.3937	1.6753
	Equal variances not assumed			.190	21.082	.851	.1408	.7399	-1.3975	1.6792
Total Number of Sleep Episodes	Equal variances assumed	.585	.452	-.902	22	.377	-.75	.83	-2.47	.97
	Equal variances not assumed			-.902	20.713	.377	-.75	.83	-2.48	.98
Percent of Time Spent i Danger Zone	Equal variances assumed	.028	.868	.095	22	.925	9.167E-03	9.670E-02	-.1914	.2097
	Equal variances not assumed			.095	21.996	.925	9.167E-03	9.670E-02	-.1914	.2097
Percent of Effectiveness During Waking Hours	Equal variances assumed	.778	.387	-.049	22	.962	-1.667E-03	3.433E-02	-7.29E-02	6.953E-02
	Equal variances not assumed			-.049	19.619	.962	-1.667E-03	3.433E-02	-7.34E-02	7.004E-02
How often do you work out per week?	Equal variances assumed	.108	.745	.779	22	.444	.25	.32	-.42	.92
	Equal variances not assumed			.779	21.993	.444	.25	.32	-.42	.92
How much tobacco do you use?	Equal variances assumed	.108	.750	-.609	10	.556	-.25	.41	-1.17	.67
	Equal variances not assumed			-.655	7.403	.532	-.25	.38	-1.14	.64
How much caffeine do you use?	Equal variances assumed	1.996	.172	.290	22	.775	8.33E-02	.29	-.51	.68
	Equal variances not assumed			.290	20.534	.775	8.33E-02	.29	-.52	.68
Gender	Equal variances assumed	12.037	.002	1.517	22	.143	.25	.16	-9.17E-02	.59
	Equal variances not assumed			1.517	17.763	.147	.25	.16	-9.65E-02	.60

Table 7.   INDEPENDENT SAMPLE T-TEST RESULTS FOR COMPARING ADJUSTED AND NON-ADJUSTED PARTICIPANTS

Table 8 displays how self-reported adjusted/non-adjusted responses compared to the amount of time a participant spent in the danger zone (FAST work efficiency less than 78%). A fascinating result is that those reporting that they had adjusted were just as likely to spend over half their time in the danger zone as those who reported that they had not adjusted. The reason could be cognitive dissonance where participants convinced themselves that they were (or were not) adjusted even though objective actigraphy data showed differently. The null hypothesis was that self-reported adjustment and actigraphy measurements are independent. The alternative is that they are related to each other. Based on an independent sample t-test (or chi-squared test of independence), there is no evidence to reject the null hypothesis (p-value = 1.00).

			Less Than 50% Time Spent in Danger Zone	Greater Than 50% Time Spent in Danger Zone	Total
Have you ever completely adjusted?	No	Observed	8	4	12
		Expected	8.0	4.0	12.0
	Yes	Observed	8	4	12
		Expected	8.0	4.0	12.0
Total		Observed	16	8	24
		Expected	16.0	8.0	24.0

Table 8.   SELF-REPORTED ADJUSTMENT WITH PERCENT OF TIME SPENT IN THE DANGER ZONE FOR 24 PARTICIPANTS.

Table 9 splits the participants into two groups based on their effectiveness during waking hours: those at or below the overall median (79%), and those above the median. Cognitive dissonance may also be the explanation for the results seen in Table 9. Instead of falling into higher effectiveness block, half (6 out of 12) of the adjusted participants fell in the lower block. Likewise, roughly half of the non-adjusted fell into the higher effectiveness block. The null hypothesis was that self-reported adjustment and actigraphy measurements are independent. There was no evidence to reject the null hypothesis (p-value = 0.96).

			Less Than or Equal to 79% Effectiveness During Waking Hours	Greater than 79% Effectiveness During Waking Hours	Total
Have you ever completely adjusted?	No	Observed	7	5	12
		Expected	6.5	5.5	12.0
	Yes	Observed	6	6	12
		Expected	6.5	5.5	12.0
Total		Observed	13	11	24
		Expected	13.0	11.0	24.0

Table 9.   SELF-REPORTED ADJUSTMENT AND EFFECTIVENESS DURING WAKING HOURS

3.   Topside Versus Belowdecks Conditions

Based on questions #1a, #1b, and #16 on the STENNIS survey and questions #13 and #14 on the demographic survey, the participants were categorized as working topside or working belowdecks. This set of comparisons yielded the greatest number of significant differences—and most important findings—in the study. Tables 10 and 11 show this clearly. Notice the mean differences of average sleep episode duration, average daily sleep, total number of sleep episodes, percent of time the participants were

in the danger zone, and the average waking effectiveness were all highly significantly (p-value< 0.03) for the topside and belowdecks conditions.   The mean values in Table 10 show that those working topside were better on all the above measures.   All other comparisons failed to reach statistical significance (p-values>0.22).

	Topside/Belowdecks	N	Mean	Std. Deviation	Std. Error Mean
Days on current watch rotation	0 Topside	12	52.08	29.52	8.52
	1 Belowdecks	12	57.00	32.96	9.51
Average Watch Length	0 Topside	12	8.17	3.59	1.04
	1 Belowdecks	12	8.75	3.44	.99
Average Sleep Episode Duration in Hours	0 Topside	12	3.6392	1.4686	.4240
	1 Belowdecks	12	7.3500	1.4653	.4230
Average Daily Sleep in Hours	0 Topside	12	4.8642	1.4920	.4307
	1 Belowdecks	12	7.4667	.8124	.2345
Total Number of Sleep Episodes	0 Topside	12	6.17	2.12	.61
	1 Belowdecks	12	4.08	1.31	.38
Percent of Time Spent in Danger Zone	0 Topside	12	.6592	.2237	6.458E-02
	1 Belowdecks	12	.3467	9.452E-02	2.728E-02
Percent of Effectiveness During Waking Hours	0 Topside	12	.7250	8.960E-02	2.586E-02
	1 Belowdecks	12	.8250	2.576E-02	7.437E-03
How often do you work out per week?	0 Topside	12	1.83	.72	.21
	1 Belowdecks	12	1.75	.87	.25
How much tobacco do you use?	0 Topside	5	1.80	.84	.37
	1 Belowdecks	7	1.57	.53	.20
How much caffeine do you use?	0 Topside	12	2.25	.62	.18
	1 Belowdecks	12	1.83	.72	.21
Gender	0 Topside	12	1.17	.39	.11
	1 Belowdecks	12	1.25	.45	.13
Have you ever completely adjusted?	0 Topside	12	.50	.52	.15
	1 Belowdecks	12	.50	.52	.15
How long did it take for you to adjust?	0 Topside	12	17.58	13.16	3.80
	1 Belowdecks	12	17.17	13.56	3.91

Table 10.   SUMMARY STATISTICS BY TOPSIDE/BELOWDECKS

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Days on current watch rotation	Equal variances assumed	.404	.531	-.385	22	.704	-4.92	12.77	-31.41	21.57
	Equal variances not assumed			-.385	21.739	.704	-4.92	12.77	-31.43	21.59
Average Watch Length	Equal variances assumed	.077	.783	-.406	22	.688	-.58	1.44	-3.56	2.39
	Equal variances not assumed			-.406	21.961	.688	-.58	1.44	-3.56	2.39
Average Sleep Episode Duration in Hours	Equal variances assumed	.040	.844	-6.196	22	.000	-3.7108	.5989	-4.9528	-2.4688
	Equal variances not assumed			-6.196	22.000	.000	-3.7108	.5989	-4.9528	-2.4688
Average Daily Sleep in Hours	Equal variances assumed	3.432	.077	-5.307	22	.000	-2.6025	.4904	-3.6196	-1.5854
	Equal variances not assumed			-5.307	16.996	.000	-2.6025	.4904	-3.6372	-1.5678
Total Number of Sleep Episodes	Equal variances assumed	1.105	.305	2.890	22	.008	2.08	.72	.59	3.58
	Equal variances not assumed			2.890	18.318	.010	2.08	.72	.57	3.60
Percent of Time Spent in Danger Zone	Equal variances assumed	15.874	.001	4.458	22	.000	.3125	7.011E-02	.1671	.4579
	Equal variances not assumed			4.458	14.806	.000	.3125	7.011E-02	.1629	.4621
Percent of Effectiveness During Waking Hours	Equal variances assumed	10.723	.003	-3.716	22	.001	-.1000	2.691E-02	-.1558	-4.42E-02
	Equal variances not assumed			-3.716	12.806	.003	-.1000	2.691E-02	-.1582	-4.18E-02
How often do you work out per week?	Equal variances assumed	1.441	.243	.257	22	.800	8.33E-02	.32	-.59	.76
	Equal variances not assumed			.257	21.267	.800	8.33E-02	.32	-.59	.76
How much tobacco do you use?	Equal variances assumed	.836	.382	.581	10	.574	.23	.39	-.65	1.11
	Equal variances not assumed			.538	6.315	.609	.23	.43	-.80	1.26
How much caffeine do you use?	Equal variances assumed	.127	.725	1.520	22	.143	.42	.27	-.15	.99
	Equal variances not assumed			1.520	21.560	.143	.42	.27	-.15	.99
Gender	Equal variances assumed	.957	.338	-.484	22	.633	-8.33E-02	.17	-.44	.27
	Equal variances not assumed			-.484	21.523	.633	-8.33E-02	.17	-.44	.27
Have you ever completely adjusted?	Equal variances assumed	.	.	.000	22	1.000	.00	.21	-.44	.44
	Equal variances not assumed			.000	22.000	1.000	.00	.21	-.44	.44
How long did it take for you to adjust?	Equal variances assumed	.229	.637	.076	22	.940	.42	5.45	-10.89	11.73
	Equal variances not assumed			.076	21.981	.940	.42	5.45	-10.89	11.73

Table 11.   INDEPENDENT SAMPLE T-TEST RESULTS FOR TOPSIDE/BELOWDECKS COMPARISONS

Figure 25 depicts the relationship between average daily sleep and the total number of sleep episodes, distinguishing topside and belowdecks participants. The graph illustrates that topside individuals tended to get more sleep periods although their daily sleep averages were much lower than their counterparts working belowdecks. Even though they were sleeping more often, they tended to receive much less sleep during a 24-hour period.
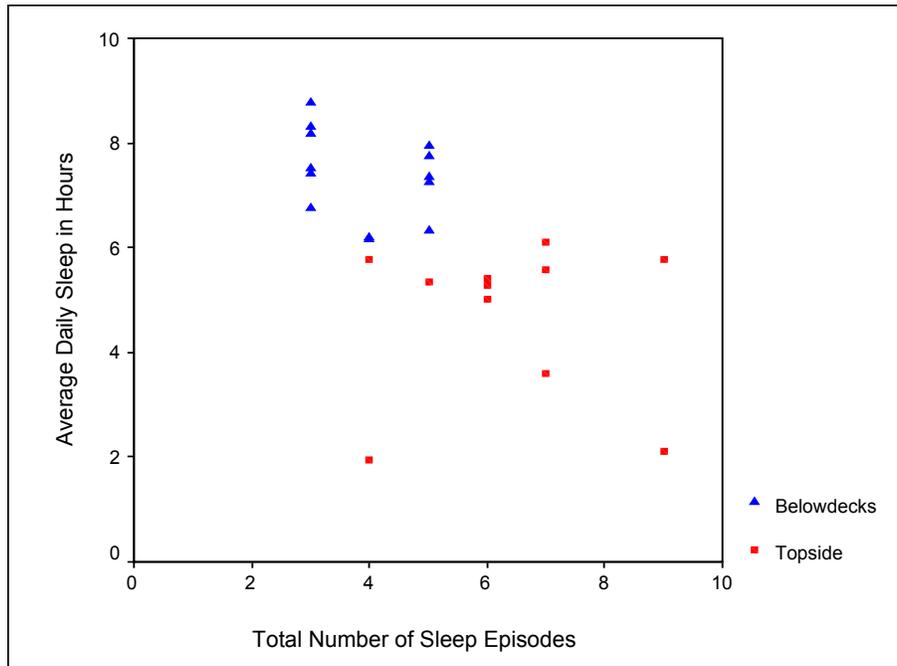
Figure 25.   **SCATTER PLOT OF AVERAGE DAILY SLEEP AND TOTAL NUMBER OF SLEEP EPISODES**

Figure 26 depicts the relationship between average daily sleep and the total number of sleep episodes, distinguishing topside and belowdecks participants. Although topside individuals tended to get more sleep periods, the durations of those sleep episodes were shorter so their sleep patterns were very disrupted. It is well known that contiguous sleep is far superior to fragmented sleep. This graph illustrates how sleep duration per episode matters. Those working belowdecks averaged fewer sleep episodes, but they slept longer and had a better quality of sleep.
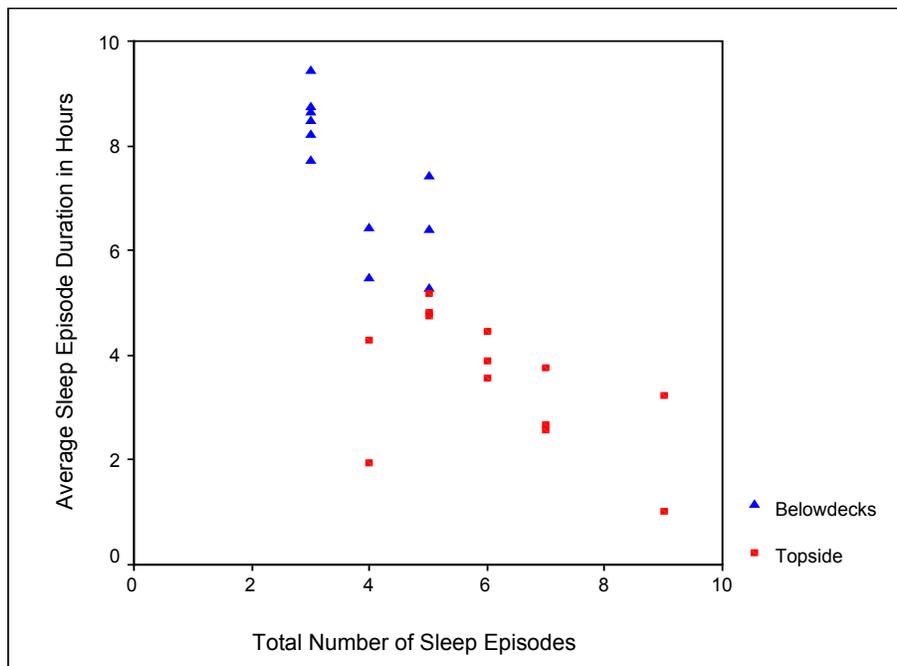
Figure 26.   **SCATTER PLOT OF AVERAGE SLEEP EPISODE DURATIONS AND TOTAL NUMBER OF SLEEP EPISODES**

One of the most interesting findings presented in Figure 27 is the difference in the percent of time participants' effectiveness fall below 78% for topside and belowdecks personnel. Those working belowdecks spent, on average, 35% of their time in the danger area. Conversely, those working topside spent a remarkably high 68% in the danger area. This 33% difference is statistically significant with p-value equal 0.00. The medians for operating in the danger zone under topside and belowdecks conditions were 67% and 38%, respectively. It is interesting to see that the ranges were quite different: 54% for topside and 31% for belowdecks. The lowest percent of time those working topside spent in the danger area was 42%. Additionally, there is more variability in the time their effectiveness was low. Figures 28 and 29 provide an astonishing picture of the divided distribution for these groups, in terms of average sleep episode and average daily sleep.
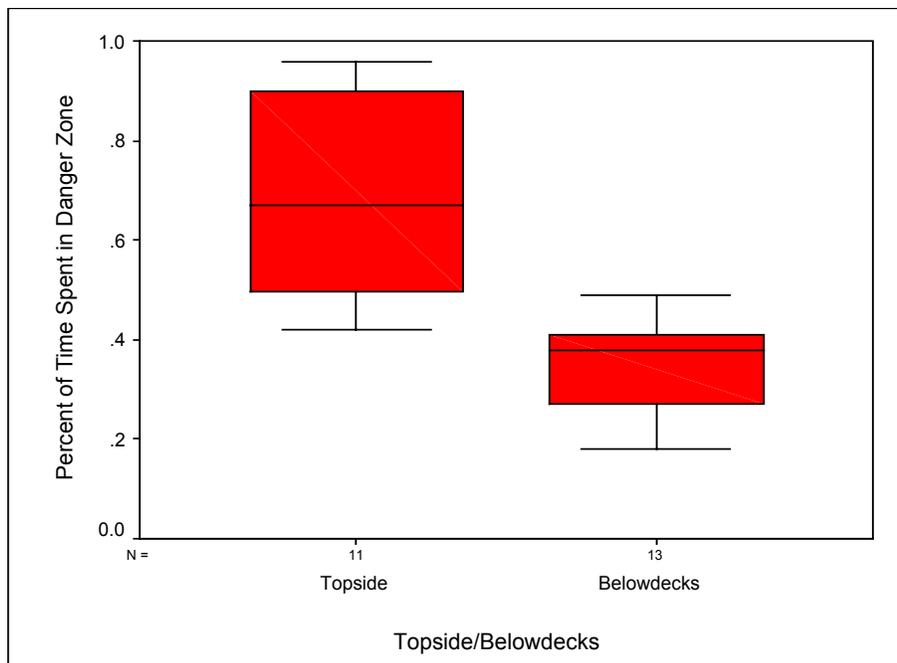
Figure 27.   **BOX PLOT OF PERCENT OF TIME SPENT IN DANGER ZONE AND TOPSIDE/BELOWDECKS CONDITION**
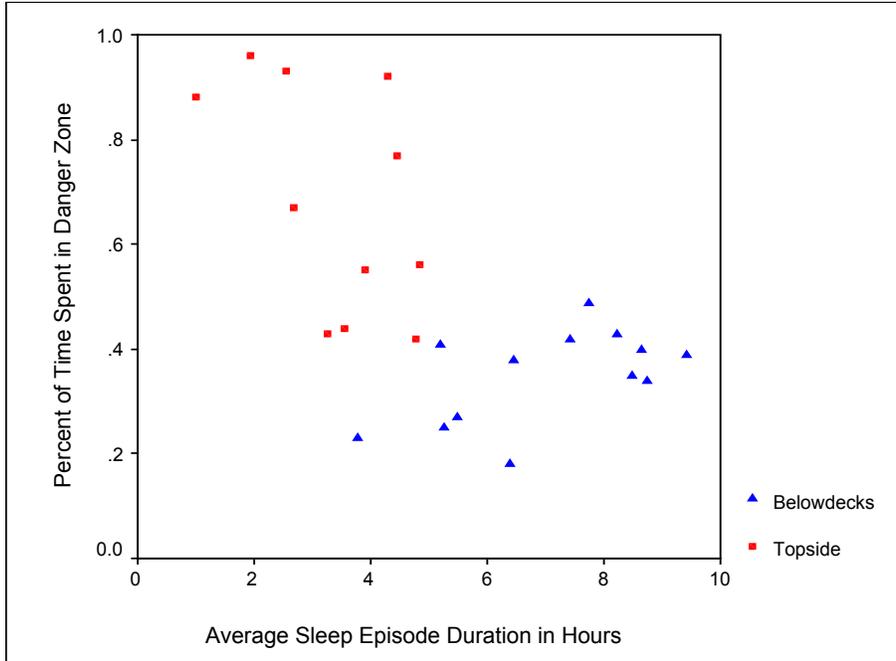
Figure 28. SCATTER PLOT OF PERCENT OF TIME SPENT IN DANGER ZONE AND AVERAGE SLEEP EPISODE DURATION
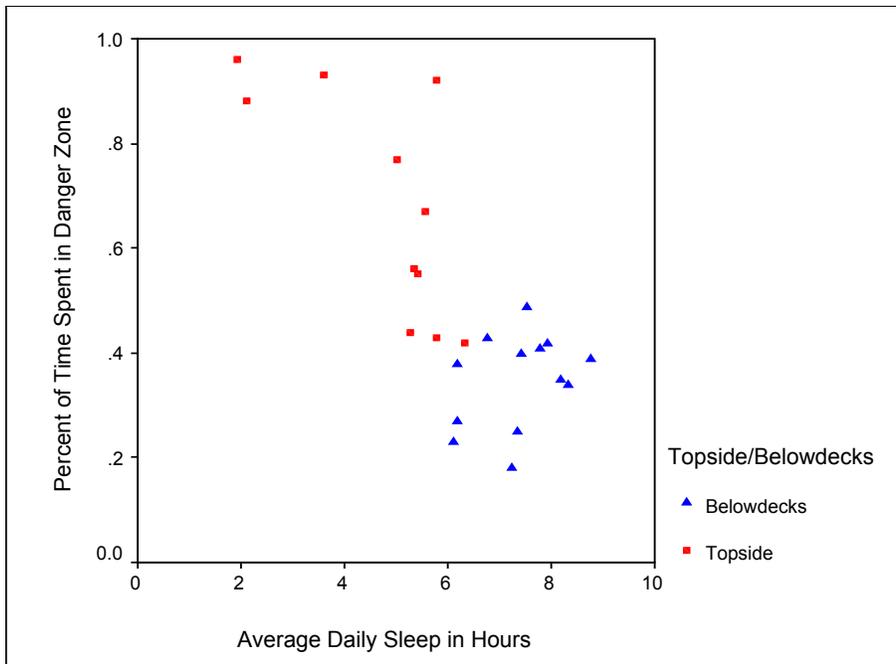
Figure 29. SCATTER PLOT OF PERCENT OF TIME SPENT IN DANGER ZONE AND AVERAGE DAILY SLEEP

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Another astonishing finding presented in Figure 30 is the difference in percent of effectiveness during waking hours for those working topside and those working belowdecks. Belowdecks and topside workers averaged 72% and 82% effectiveness while awake, respectfully. This 10% difference was statistically significant (p-value = 0.00). The medians for topside and belowdecks conditions were 76% and 82%, respectively. The ranges were 29% for those working topside and 7% for those working belowdecks. The small range indicated much less variability in the sleep patterns for those working belowdecks. The highest attained percentage (81%) of effectiveness for topside was only two percent more than what the belowdecks crew would get on a really bad day. Figures 31 and 32 demonstrate these differences using average daily sleep and average sleep episode duration.
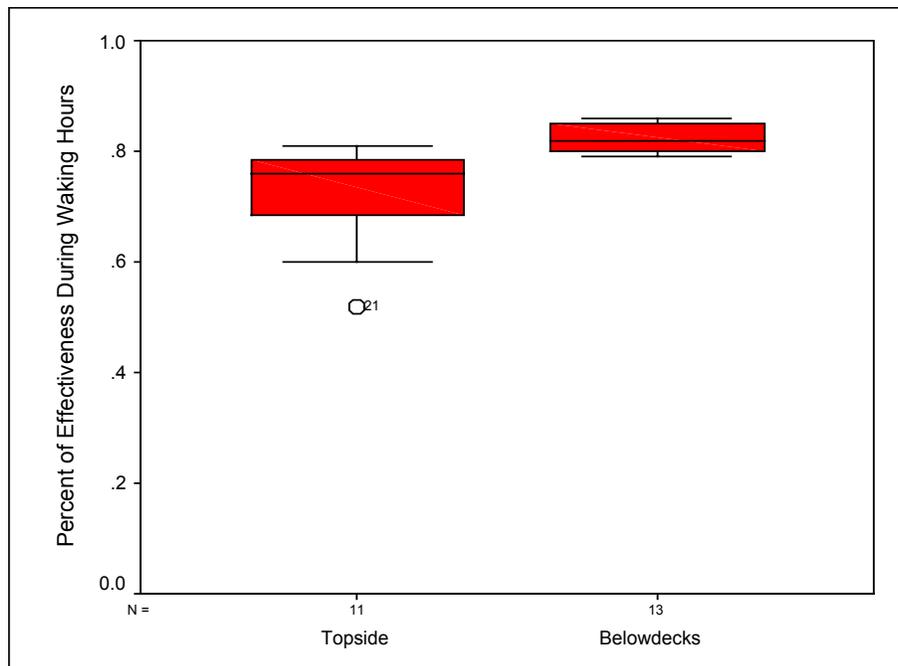
Figure 30. **BOX PLOT OF EFFECTIVENESS DURING WAKING HOURS AND TOPSIDE/BELOWDECKS CONDITION**
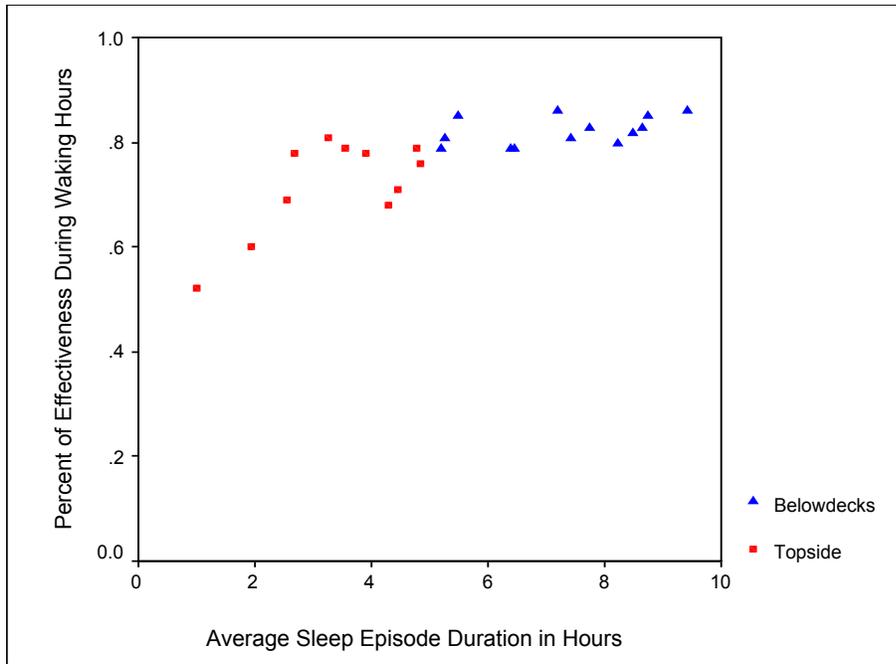
Figure 31. SCATTER PLOT OF EFFECTIVENESS DURING WAKING HOURS AND AVERAGE SLEEP EPISODE DURATION
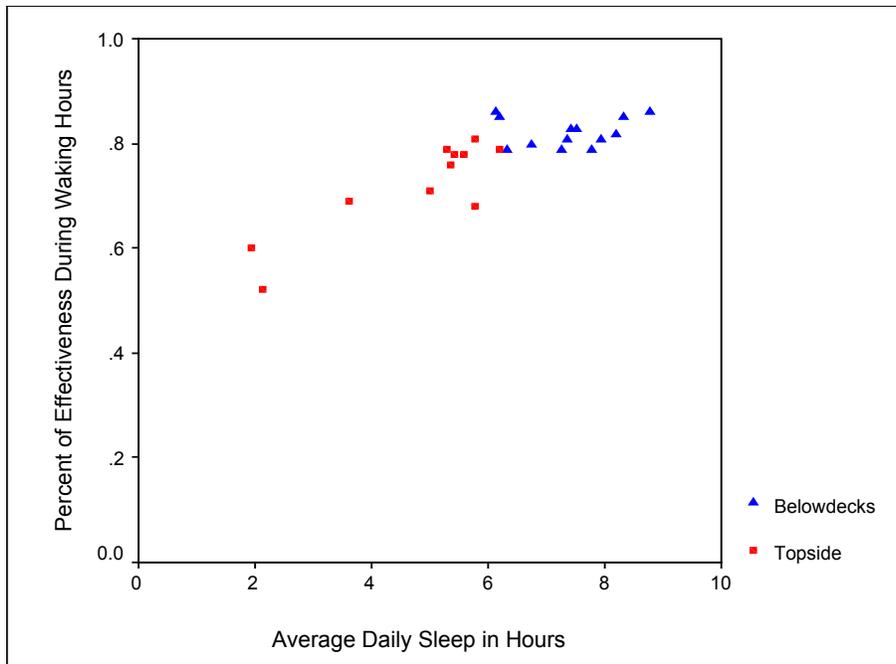
Figure 32. SCATTER PLOT OF EFFECTIVENESS DURING WAKING HOURS AND AVERAGE DAILY SLEEP

F. MULTIPLE REGRESSION ANALYSIS

The previous sections showed results for the data set either as a whole, or by dividing it into two groups. Four different but related outcomes were examined: average daily sleep, average sleep episode duration, the percent of time that participants were in the danger zone, and the overall effectiveness while awake. This section contains the results of a regression analysis of one of these outcomes: average daily sleep. First, responses to the selected questions and actigraphy results (see Table 3) were included as potential independent variables. Episodes*Topside was also included as a potential interaction variable. Then a simpler model was developed that included only those independent variables with p-values less than or equal to 0.05.

Table 12 shows the final regression model for this response. Residual plots (not shown) were generated to check for violations of any of the regression assumptions.

	Coefficient	Standard Error	P-value
Intercept	**13.94**	**2.29**	**0.00**
Days on Current Watch Rotation	**-0.02**	**0.01**	**0.05**
Topside	**-5.95**	**1.86**	**0.01**
Total Episodes	**-0.88**	**0.34**	**0.02**
Episodes*Topside	**0.79**	**0.38**	**0.05**
Average Length of Watch	**-0.20**	**0.09**	**0.03**
R-square = 0.69	**Standard Error = 1.11**		**Overall P-value = 0.00**

Table 12.   REGRESSION TABLE FOR AVERAGE DAILY SLEEP

The overall regression equation is given below. The model explains 69% of the variability in this response. For convenience, separate regression equations corresponding to topside and belowdecks conditions are also provided.

Predicted Average Daily Sleep = 13.94

- 0.02 * (Days on Current Watch)

-5.95 * (Topside) - 0.88 * (Total Episodes)

+ 0.79*(Topside x Total Episodes) - 0.20*(Avg Length of Watch)

Topside Predicted Average Daily Sleep = 7.99

- 0.02 * (Days on Current Watch) - 0.09 * (Total Episodes)

- 0.20*(Avg Length of Watch)

Belowdecks Predicted Average Daily Sleep = 13.94

- 0.02 * (Days on Current Watch) - 0.88 * (Total Episodes)

- 0.20*(Avg Length of Watch)

The results show that, all else being equal, long watch lengths were associated with lower average daily sleep. The negative coefficient for days on the current watch indicates that the lower sleep was not alleviated by time spent on a particular watch schedule. Those working topside got substantially less sleep than those working belowdecks (the coefficient for Topside = -5.95 hours) and even those who managed to get their sleep during fewer sleep episodes received limited benefits (coefficient for Total Episodes is near zero). On the other hand, while those working belowdecks got more sleep, sleep fragmentation had a greater negative impact on their average daily sleep (coefficient for Total Episodes = -0.88).

V.   DISCUSSION AND RECOMMENDATIONS

A.   DISCUSSION

The purpose of this study was to examine whether fatigue and sleep patterns of crewmembers aboard the USS JOHN C. STENNIS were affected by reversing the sleep-wake cycles. The results indicate that reversing the sleep-wake cycle had a profound affect on the sleep patterns and reported fatigue levels of the sailors in this study. Based on the results presented in Chapter IV, it is quite clear that a large number (nearly 50 percent) of the participants in this study reported that they had not yet adjusted to this reversed schedule. Participants' reported level of adjustment was not a good indicator of actual adjustment as shown by objective actigraphy data. We found differences in the quality and quantity of sleep between those participants working topside as compared to those working belowdecks. Working topside dramatically lowered both the amount of sleep participants receive on a daily basis as well as the average length of their sleep episodes. Additionally, this analysis showed that the predicted effectiveness (using the Fatigue Avoidance Scheduling Tool) of individuals working topside was clearly degraded.

Other factors may have contributed to the differences we observed in sleep hours and predicted effectiveness, e.g., working conditions, light exposure levels, type of work performed, health issues, and combat stress. It is important to remember that the sample used in this study may not be representative of the entire population of sailors in the U.S. Navy and that broad generalizations concerning the entire surface warfare community should not be made based on the results of this thesis. However, the fact should not be disregarded that nearly 50 percent of the study population reported that they had not yet adjusted to this reversed work schedule.

Based on the results of this thesis and the knowledge that many sailors and Marines are working on these reversed schedules, there is an urgent need to improve how we address the issues of sleep and fatigue for our military personnel. The substantial difference in the quantity and quality of sleep for individuals working topside is a major

cause for concern. It is evident that sleep deprivation and fatigue due to the reversed schedule was a major problem for the participants in this study. We hope that these findings will serve as a catalyst for others to examine these issues further.

B.   RECOMMENDATIONS

A more detailed study with baseline data on participants and/or a control group is needed to explain the substantial differences in sleep between individuals working topside and belowdecks. Study participants should be chosen to provide for an adequate assessment of work conditions, watchstanding schedules, light exposure, type of work, and gender differences. In addition to actigraphy and detailed activity logs, salivary melatonin levels should be collected to determine the influence of ambient light on sleep patterns. Standardized measures of human performance should be collected to document any performance decrements that may be attributed to inadequate sleep.

Educating military commanders on the consequences of sleep deprivation and ways to combat sleep debt in order to optimize performance is a major step in addressing fatigue and sleep related problems. Commanders should consider gradually phasing in any operation that requires rotation of personnel from a day to night watch schedule. Work-rest schedules should be altered away from the four-on, four-off rotation because this schedule does not allow for a continuous sleep period of at least 4.5 – 5.5 hours of continuous sleep.

Other ways to minimize sleep deprivation and increase quality and quantity of sleep include the following suggestions. Wear dark glasses when working or going topside prior to sleep to avoid melatonin suppression. Try scheduling the shift rotation prior to sunrise to prevent sunlight exposure for watchstanders who are working topside. Sleep in a darkened bunk with minimal light exposure. Monitor intake of caffeine and nicotine in the hours before bedtime. Finally, as a last resort, consider pharmacological interventions such as melatonin supplements.

APPENDIX A. CONFIGURING ACT MILLENNIUM (AMBULATORY MONITORING, INC.)

Before proceeding to initialize or download any actigraphs, it would be a good idea to configure ACT Millennium to match your existing hardware. This is accomplished by selecting the Configuration: Edit item. In addition to editing your configuration, you can save the new configuration, load up your last saved configuration, and reset your configuration to the default values.

The figure below shows the configuration window when the Edit item is selected. Notice the four tabs appearing at the top. These tabs permit you to select which configuration parameters need to be set. Choose the Interface type that matches your hardware.
Note: Manual-switching interface was selected for use.
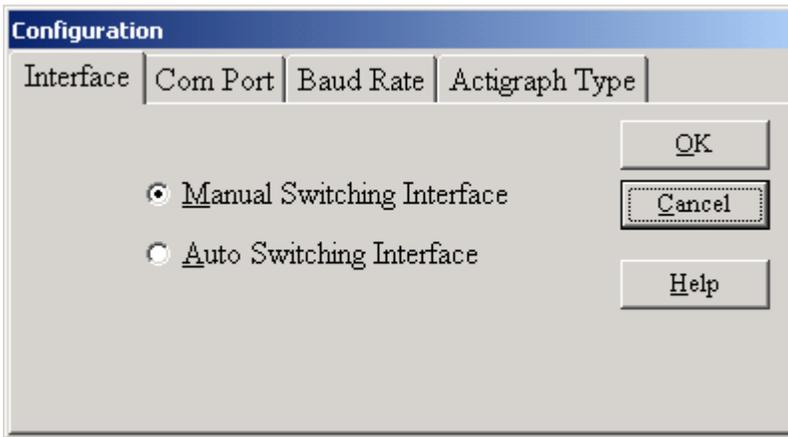
Pressing the Com Port Tab shows this selection. Here is the serial port selection. Choose the computer port that you have attached your interface unit to.
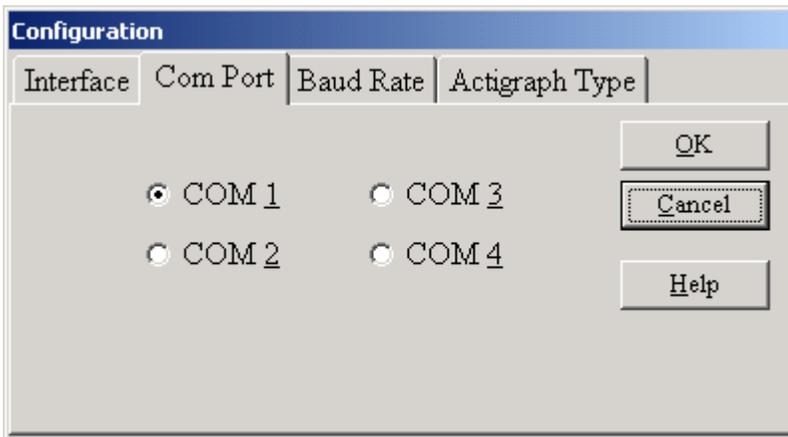
Selecting the Baud Rate Tab shows this screen.   The Automatic Interface cannot support any settings above 9600 baud.
Note: 38400-baud rate was selected for use.
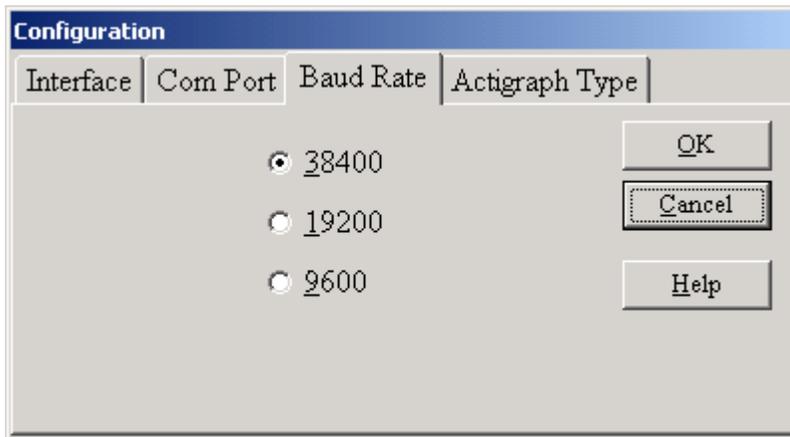
Choosing the Actigraph Type Tab causes this screen to be displayed. Choose the actigraph type you currently want to use.
Note. Sleep-O type was selected for use.
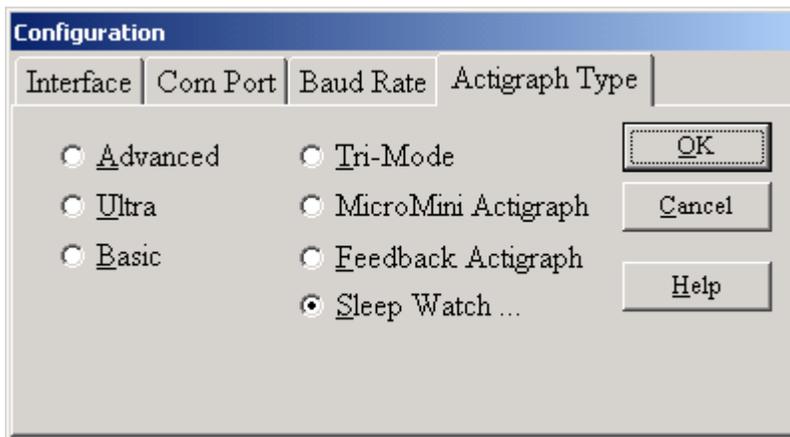
After completing your configuration settings, make sure that you save it (Configuration: Save).   Save as "dat" and "ami".   You don't want to restart ACT Millennium later and reselect these settings again. If you are like me, you will waste a couple of hours wondering why you can't communicate with your actigraph when it worked just fine yesterday.

APPENDIX B.   INITIALIZING ACTIGRAPH
(AMBULATORY MONITORING, INC)

   To initialize an actigraph, select the Actigraph: Initialize menu item or simply click the button. Make sure that your actigraph is seated in the interface. The first dialog box to appear is shown in the figure below. This box permits you to correctly set the computer's time and date. If you would like to change the time and date just type in the correct month, day, year, hour, minutes and seconds. Then click the Set Current Time button to set the time. If you just want to keep the computer's time, just click on the Continue button.

Note: Current time was selected for use.

   Next a selection of the actigraph type is presented as shown in the figure below. ACT Millennium supports all actigraph types currently sold by Ambulatory Monitoring (Advanced to MicroMini). To continue select the desired actigraph type and press OK.

Note: Sleep Watch was selected for use.

Now a dialog box is shown which permits you to chose an actigraph sampling mode as shown in the figure below. You should see different selections of sampling modes depending upon the actigraph type you chose in the previous dialog box. Just select the desired mode and press OK to continue.

Note: PIM/ZCM/TAT was selected for use.
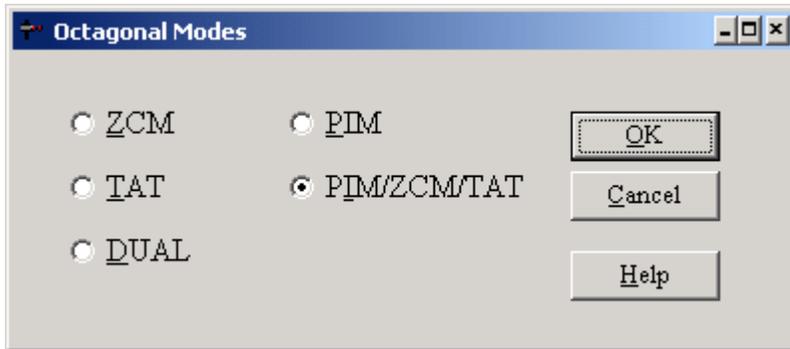
Depending on the actigraph type and sampling mode selected, you may have the option of choosing whether or not to record events or have audio feedback. If you do, you will see the dialog box shown in the figure below. Just make sure the features you want are checked (and the ones you don't are not) and click OK to continue.

Note: Record events were checked.

Again depending on the actigraph type and sampling mode selected, you may have to select an Epoch length. If needed an Epoch Length dialog box will be displayed as shown in the figure below. Just select the desired epoch length and press OK to continue.

Note: Epoch of 1 minute was selected for use.
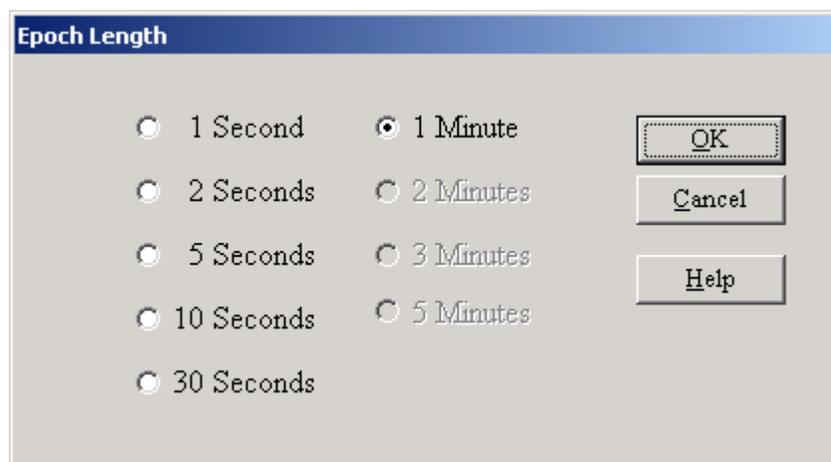
Next you will need to enter in an ID for your actigraph sampling session. The figure below shows the dialog box used to type in an actigraph ID. After entering the correct ID, click the OK button to continue.

Note: Actigraph serial numbers were used as actigraph ID.
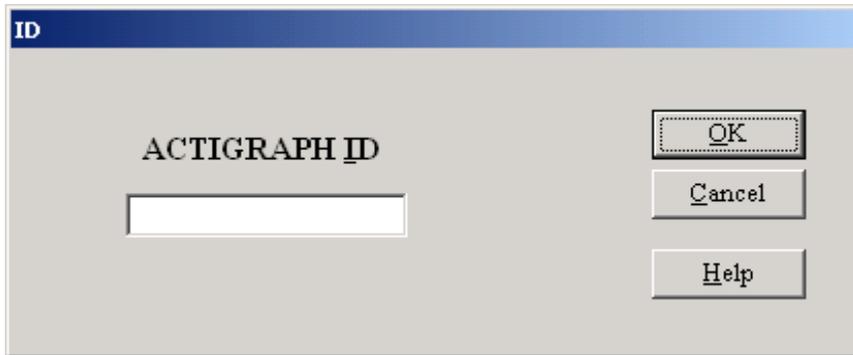
Now you will need to decide whether the actigraph will start immediately (within three minutes) or start in some future time. The figure below shows the dialog box that is used to make that decision. If you decide to start up at some future date, you will be presented with the dialog box shown in the figure below. You will have to enter in the month, day, year, hour and minute of when you want the actigraph to start up. Just click on which startup condition you want and then click the OK button to continue.

Note: Immediate startup condition was selected for use.
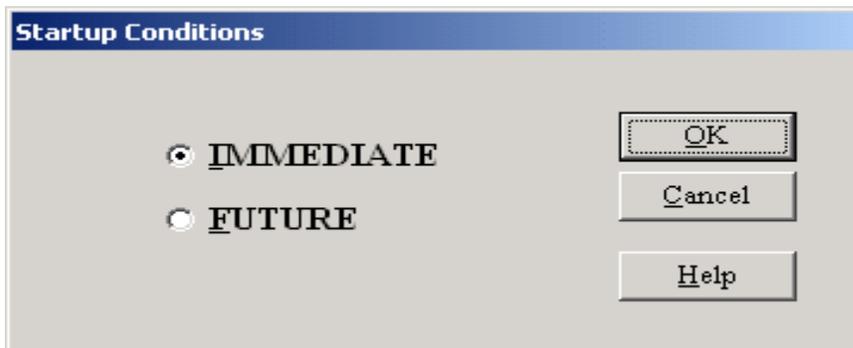
Before the initialization is started, ACT Millennium displays a preview header (the figure below) to show you how the unit will be set up. If this is an acceptable setup then click the OK button to continue.

To ensure that you really want to initialize the actigraph (which will erase any previous data) an Overwrite verification dialog box is displayed (the figure below). If you are sure that you want to initialize the actigraph press Yes.
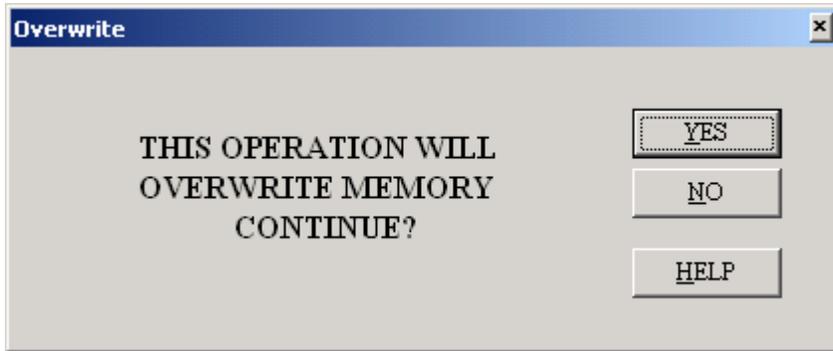
Once you decide to begin actigraph initialization, a window shown in the figure below is displayed. This permits you to abort the actigraph initialization process in case you change your mind or an error occurs.

Clicking the abort button will stop the actigraph initialization and display the message box shown in the figure below.

If the actigraph is initialized successfully, then the message box shown in the figure below is displayed. You may now remove the actigraph and begin using it.

APPENDIX C.   DOWNLOADING ACTIGRAPH
(AMBULATORY MONITORING, INC)

To transfer the contents of the actigraph to your computer, first place the actigraph into the interface unit. Then press the button or select Actigraph: Download. At this point the program will verify that you have the actigraph and interface ready for communication with the window shown in the figure below.

Pressing OK will begin the download process. A progress window as shown in the figure below will be displayed. The user has the option of stopping the transfer by pressing the Abort Button.

Upon the successful download of data, you will be presented with the option of saving your download.

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APPENDIX D.   PARTICIPANT CONSENT FORM

1. **Introduction.** You are invited to participate in a study of fatigue and circadian rhythms. With information gathered from you and other participants, we hope to gain insight into how easily sailors adjust to major shifts in their sleep cycles. We ask you to read and sign this form indicating that you agree to be in the study. Please ask any questions you may have before signing.

2. **Background Information.** The Naval Postgraduate School Navy Fatigue Countermeasures Research Group is conducting this study.

3. **Procedures.** If you agree to participate in this study, the researcher will explain the tasks in detail. Data will be collected over a 72-hour period during which, every three hours while you are awake, you will be expected to fill out a survey that describes your normal and preferred sleep habits, to measure and record your oral temperature and to record an estimation of your subjective feeling of "sleepiness". You may also be asked to wear a wristwatch device, which measures your activity levels. Additional data may include simple performance measures of reaction time, which could take approximately 5 minutes to complete.

4. **Risks and Benefits.**   This research involves no risks or discomforts other than those experienced when having oral (under the tongue) temperatures taken and wearing a wristwatch. There are no direct benefits to you for your participation. The indirect benefits are that you will be contributing to current research in human fatigue as well as contributing to the "lessons learned" for sustained combat night operations.

5. **Compensation.** No tangible reward will be given. A copy of the results will be available to you at the conclusion of the study.

6. **Confidentiality.** The records of this study will be kept confidential. No information will be publicly accessible which could identify you as a participant.

7. **Voluntary Nature of the Study.** If you agree to participate, you are free to withdraw from the study at any time without prejudice. You will be provided a copy of this form for your records.

8. **Points of Contact.** If you have any further questions or comments after the completion of the study, you may contact the research supervisor, Dr. Nita Lewis Miller (831) 656-2281 or email nlmiller@nps.navy.mil.

9. **Statement of Consent.** I have read the above information. I have asked all questions and have had my questions answered. I agree to participate in this study.

---   --------------------------
Participant's Signature   Date

---   --------------------------
Researcher's Signature   Date

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APPENDIX E.   MINIMAL RISK CONSENT FORM

Participant: **VOLUNTARY CONSENT TO BE A RESEARCH PARTICIPANT IN THE EFFECTS OF REVERSING SLEEP-WAKE CYCLES ON SLEEP AND FATIGUEON THE CREW OF USS JOHN C. STENNIS**

1. I have read, understood and been provided "Information for Participants" that provides the details of the below acknowledgments.

2. I understand that this project involves research. An explanation of the purposes of the research, a description of procedures to be used, identification of experimental procedures, and the duration of my participation have been provided to me.

3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

6. I have been informed of any compensation and/or medical treatments available if injury occurs and is so, what they consist of, or where further information may be obtained.

7. I understand that my participation in this project is voluntary; refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

8. I understand that the individual to contact should I need answers to pertinent questions about the research is Professor Nita Lewis Miller, Principal Investigator, and about my rights as a research participant or concerning a research related injury is the Operations Research Department Chairman. A full and responsive discussion of the elements of this project and my consent has taken place.

      Medical Monitor: Flight Surgeon, Naval Postgraduate School

_____
Signature of Principal Investigator   Date

_____
Signature of Volunteer   Date

_____
Signature of Witness   Date

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APPENDIX F.   PRIVACY ACT FORM

1. Authority: Naval Instruction

2. Purpose: Activity levels, oral temperatures, subjective fatigue, and simple human performance data will be collected to enhance knowledge, and to develop recommendations for making major changes in shift work schedules of USN personnel.

3. Use: Data will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was collected. Use of the information may be granted to legitimate non-government agencies or individuals by the Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act.

4. Disclosure/Confidentiality:

    a. I have been assured that my privacy will be safeguarded. I will be assigned a control or code number, which thereafter will be the only identifying entry on any of the research records. The Principal Investigator will maintain the cross-reference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which are not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

    b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 3 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

    c. I also understand that disclosure of the requested information, including my Social Security Number, is voluntary.

_____
Signature of Volunteer   Name, Grade/Rank (if applicable)

_____
DOB   SSN   Date

_____
Signature of Witness   Date

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APPENDIX G.   DEMOGRAPHIC QUESTIONAIRE

1. How many days have you been on your current watch rotation?_____

2. What is the average length of your watch? _____ hours

3. Age: _____

4. Gender: Male   Female

5. Height: ____ ft ____ in   Weight: _____ lb

6. What was your last PRT score? _____

7. In the past four weeks, have you been able to work out?   (circle one)

    0 – 1 times per week   2-3 times per week   4 or more times per week

Nicotine Use

8. Do you use any tobacco products?   Yes   No

    If yes, what? _____

    How much and how often? _____

    Do you use nicotine gum?_____

    Have you been using MORE tobacco products since going on this work/sleep

    schedule? (circle one): Less   Same   More

Caffeine Consumption

9. How many caffeinated beverages do you consume in an average 24-hour period in each

    category?

    Coffee_____ Caffeinated Soda_____ Tea (hot or iced)_____

    Have you been drinking MORE caffeinated beverages since going on this work/sleep

    schedule? (circle one): Less   Same   More

Medications

10. List any medications (either over-the-counter or prescription) that you are currently
    taking:_____
    Has the amount or type of medications changed on this work/sleep schedule? Please describe
    how:_____

Military Experience

11. How long have you served in the Unites States Armed Forces?_____years
    Branch: _____ Current Rank/Rating: _____

Education / Work Background

12. What is the highest level of education you have achieved to date? (GED/High School
Diploma, AA, BA/BS, etc.)? _____

13. In what division and department are you assigned? _____

14. Are you ship's company or are you assigned to the Air Wing?_____

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APPENDIX H.   STENNIS QUESTIONAIRE

1. How difficult was it for you to make the transition from daytime (work) to daytime (sleep)?

Very Easy	Easy	Neutral	Hard	Very Hard
1	2	3	4	5

   1a. If it was hard to adjust to daytime sleep, what made it difficult?

   _____

   1b. What things/cues (other than daylight/dark) made it hard to adjust?

   _____

2. Was it hard for other people onboard to adjust?

Very Easy	Easy	Neutral	Hard	Very Hard
1	2	3	4	5

3. Which Division/Department seemed to have the most difficulty in adjusting?

   _____

4. Did you ever completely adjust?   Yes   No

5. How long did it take for you to adjust?   _____ days

6. Do you think you got more or less sleep on this schedule? (circle one) More   Same   Less

7. Is the quality of your sleep worse or better now than before you switched? (circle one)
A: Sleep quality is worse now than before   **B:** Sleep quality is the same   **C:** Sleep quality is better.

8. Compared to how I usually feel when I leave work after working during the day, on this schedule after working all night, I feel: (circle one) **A:** more exhausted **B:** the same **C:** less exhausted.

Use the following scale to answer questions 9 through 15:

1	2	3	4	5
Never	Rarely	Sometimes	Often	Always

____9. How often do you have difficulty falling asleep?
____10. How often do you have trouble waking up or getting out of bed?
____11. How often after falling asleep do you wake-up early and can't get back to sleep again?
____12. How often do you feel so tired on watch that you can't concentrate and need help staying awake
____13. How often do you feel physically of mentally tired during your watch?
____14. How often do you feel overly tired or have difficulty staying awake?
____15. Do you feel as though you get enough sleep?

16. The WORST thing about this schedule was: _____

17. The BEST think about this schedule was: _____

18. Please list any comments or suggestions on the back of the page.

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APPENDIX I.   LARK AND OWL SURVEY

Take the following survey to help us determine if you are a lark, an owl or somewhere in between. These questions should be answered as if you were **at home and not deployed!**

Circadian Identity

1.)   What   time   would   you   get   up   if   you   were   entirely   free to plan your day?

- ○   Before 7 a.m.
- ○   7-9 a.m.
- ○   After 9 a.m.

2.) How easy is it for you to get up on workdays?

- ○   Fairly easy
- ○   Moderately difficult/depends on the day
- ○   Very difficult

3.)   How   alert   do   you   feel   during   the   first   30   minutes   after you get up in the morning?

- ○   Alert/fresh
- ○   Varies
- ○   Sleepy/tired

4.) What time would you go to bed if it were completely up to you?

- ○   Before 10:30 p.m.
- ○   10:30 p.m. - midnight
- ○   After midnight

5.)   How   sleepy/tired   are   you   1½   hour   before   going   to   bed during the workweek?

- ○   Very tired/ready to fall asleep
- ○   Moderately tired/depends on the day
- ○   Not very tired

6.)   When   you've   stayed   up   later   than   usual   (had   a   late   evening), when   do   you   wake   up   the   next   morning   (assuming   you   didn't have any alcohol)?

- ○   At your usual time, with a desire to get out of bed
- ○   Varies
- ○   Later than usual, with a desire to fall back asleep

Flex-Ability Quotient

1.) When you are feeling drowsy, can you easily overcome it if there is something important you have to do?

   ⭕ Rarely

   ⭕ Sometimes

   ⭕ Usually

2.) When you have to do something important in the middle of the night, can you do it almost as easily as you could at a more normal time of day?

   ⭕ Rarely

   ⭕ Sometimes

   ⭕ Usually

3.) Do you enjoy working at unusual times of the day or night?

   ⭕ Rarely

   ⭕ Sometimes

   ⭕ Usually

4.) If you have a lot to do, can you stay up late or get up very early to finish it without feeling too tired?

   ⭕ Rarely

   ⭕ Sometimes

   ⭕ Usually

5.) Do you find it as easy to work late at night as you do earlier in the day?

   ⭕ Rarely

   ⭕ Sometimes

   ⭕ Usually

6.) Do you find it fairly easy to sleep whenever you want to?

   ⭕ Rarely

   ⭕ Sometimes

   ⭕ Usually

APPENDIX J.   72-HOUR ACTIVITY AND TEMPERATURE LOG

INSTRUCTIONS AND EXAMPLE ON OTHER SIDE

Start Date_____   Actigraph Number_____   Participant Number _____

Clock	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
Act Time																								
S Rating																								
Temp																								
Activity																								

Clock	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
Act Time																								
S Rating																								
Temp																								
Activity																								

Clock	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
Act Time																								
S Rating																								
Temp																								
Activity																								

Clock	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
Act Time																								
S Rating																								
Temp																								
Activity																								

Please use a black or blue ink pen - no pencils please!

NOTES/COMMENTS (Please add any notes about your work and sleep patterns, or other information that you feel would be helpful:)

INSTRUCTIONS

1. Enter the **START DATE** and your **PARTICIPANT NUMBER** (not your name), and the **ACTIGRAPH NUMBER** where indicated on the other side of this form.

2. When you **AWAKEN** and for **EVERY THREE HOURS** you are awake, record the **ACTUAL TIME** on the <u>Act Time</u> row (for example, 00:12) and then record the following two items:

  2a. <u>SLEEPINESS RATING</u> **("S Rating")**
Record your sleepiness rating (**1** to **7**) in the <u>**S Rating**</u> row:
   1 = *Feeling active and vital; alert; wide awake.*
   2 = *Functioning at a high level, but not at peak; able to concentrate.*
   3 = *Relaxed; awake; not at full alertness; responsive.*
   4 = *A little foggy; not at peak; let down.*
   5 = *Fogginess; beginning to lose interest in remaining awake; slowed down.*
   6 = *Sleepiness; prefer to be lying down; fighting sleep; woozy.*
   7 = *Almost in reverie; sleep onset soon; lost struggle to remain awake.*

2b. <u>TEMPERATURE in Fahrenheit</u> **("Temp")**
Take and record your temperature in the <u>**Temp**</u> row. **Do not eat or drink** anything for at least **15 minutes prior** to taking your temperature. **Do not talk** while taking your temperature. If your thermometer appears to be inaccurate, please ask for a new one.

3. <u>ACTIVITY RATING</u> **("Activity")**
Indicate when you are **ASLEEP** (including naps) or at **WORK** every **HALF HOUR** using the following activity codes. Record the appropriate code (*W, S or T*) in the <u>**Activity**</u> row:
   W = *Working*
   S = *Sleeping*
   T = *Trying to sleep*
   (W----W, S---S, T---T is OK)

4. <u>SLEEP QUALITY</u> **("Activity")**
Following each sleep or nap period, record the quality of each **SLEEP** or **NAP** in the same <u>**Activity**</u> row using these codes:
   A = *Extremely good*   **C** = *Moderately poor*
   B = *Moderately good*   **D** = *Extremely poor*

EXAMPLE

Clock	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Act Time	0012			0258			0555			0910			1307			1607			1904			2226		
S Rating	4			3			5			5			2			1			2			2		
Temp	98.5			98.1			98.2			98.3			98.5			98.7			98.7			98.5		
Activity	W--	-- --	-- --	-- --	-- --	-- --	--W			T S	-- --	-- S	T B							T T	S --	S D		

Please use a black or blue ink pen - no pencils please!
Please make every effort to be accurate.
Your data will be extremely useful in our effort to improve the safety and quality of life of our fighting men and women. Thank you.

Please return this form to: **LT John Nguyen or**   **Or mail to:**   **Dr. Nita Miller**
                          LT Chris Front (Ship's Psychologist)   **Operations Research Department Code OR/MN**
                                                                 Naval Postgraduate School
                                                                    Monterey, CA 93943
                                                                    Phone: (831) 656-2281   DSN: 878
   **FAX: (831) 656-2458**

NAME _____ DATE _____

SEX: Male Ⓜ   Female Ⓕ

IDENTIFICATION

Below is a list of words that describe feelings people have. Please read each one carefully. Then fill in ONE circle under the answer to the right which best describes HOW YOU HAVE BEEN FEELING DURING THE PAST WEEK INCLUDING TODAY.

The numbers refer to these phrases.

```
0 = Not at all
1 = A little
2 = Moderately
3 = Quite a bit
4 = Extremely
```

Col Ⓒ   O.P. Ⓞ

	NOT AT ALL	A LITTLE	MODERATELY	QUITE A BIT	EXTREMELY
1. Friendly	⓪	①	②	③	④
2. Tense	⓪	①	②	③	④
3. Angry	⓪	①	②	③	④
4. Worn out	⓪	①	②	③	④
5. Unhappy	⓪	①	②	③	④
6. Clear-headed	⓪	①	②	③	④
7. Lively	⓪	①	②	③	④
8. Confused	⓪	①	②	③	④
9. Sorry for things done	⓪	①	②	③	④
10. Shaky	⓪	①	②	③	④
11. Listless	⓪	①	②	③	④
12. Peeved	⓪	①	②	③	④
13. Considerate	⓪	①	②	③	④
14. Sad	⓪	①	②	③	④
15. Active	⓪	①	②	③	④
16. On edge	⓪	①	②	③	④
17. Grouchy	⓪	①	②	③	④
18. Blue	⓪	①	②	③	④
19. Energetic	⓪	①	②	③	④
20. Panicky	⓪	①	②	③	④

	NOT AT ALL	A LITTLE	MODERATELY	QUITE A BIT	EXTREMELY
21. Hopeless	⓪	①	②	③	④
22. Relaxed	⓪	①	②	③	④
23. Unworthy	⓪	①	②	③	④
24. Spiteful	⓪	①	②	③	④
25. Sympathetic	⓪	①	②	③	④
26. Uneasy	⓪	①	②	③	④
27. Restless	⓪	①	②	③	④
28. Unable to concentrate	⓪	①	②	③	④
29. Fatigued	⓪	①	②	③	④
30. Helpful	⓪	①	②	③	④
31. Annoyed	⓪	①	②	③	④
32. Discouraged	⓪	①	②	③	④
33. Resentful	⓪	①	②	③	④
34. Nervous	⓪	①	②	③	④
35. Lonely	⓪	①	②	③	④
36. Miserable	⓪	①	②	③	④
37. Muddled	⓪	①	②	③	④
38. Cheerful	⓪	①	②	③	④
39. Bitter	⓪	①	②	③	④
40. Exhausted	⓪	①	②	③	④
41. Anxious	⓪	①	②	③	④
42. Ready to fight	⓪	①	②	③	④
43. Good natured	⓪	①	②	③	④
44. Gloomy	⓪	①	②	③	④

	NOT AT ALL	A LITTLE	MODERATELY	QUITE A BIT	EXTREMELY
45. Desperate	⓪	①	②	③	④
46. Sluggish	⓪	①	②	③	④
47. Rebellious	⓪	①	②	③	④
48. Helpless	⓪	①	②	③	④
49. Weary	⓪	①	②	③	④
50. Bewildered	⓪	①	②	③	④
51. Alert	⓪	①	②	③	④
52. Deceived	⓪	①	②	③	④
53. Furious	⓪	①	②	③	④
54. Efficient	⓪	①	②	③	④
55. Trusting	⓪	①	②	③	④
56. Full of pep	⓪	①	②	③	④
57. Bad-tempered	⓪	①	②	③	④
58. Worthless	⓪	①	②	③	④
59. Forgetful	⓪	①	②	③	④
60. Carefree	⓪	①	②	③	④
61. Terrified	⓪	①	②	③	④
62. Guilty	⓪	①	②	③	④
63. Vigorous	⓪	①	②	③	④
64. Uncertain about things	⓪	①	②	③	④
65. Bushed	⓪	①	②	③	④

MAKE SURE YOU HAVE
ANSWERED EVERY ITEM.

POM 021

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APPENDIX L.   ACTION-W2 PRINTOUTS FOR ALL PARTICIPANTS

File   Edit   View   Statistics   Analyze   Options   Database   Window   Help

Sleep Algorithm   Database
Cole-Kripke (rescore)   stennis.adb

Fri 2/1/2002

Sat 2/2/2002

Sun 2/3/2002

0900   1500   2100   0300   0900

File   Edit   View   Statistics   Analyze   Options   Database   Window   Help

Sleep Algorithm   Database
Cole-Kripke (rescore)   stennis.adb

Fri 2/1/2002

Sat 2/2/2002

Sun 2/3/2002

0900   1500   2100   0300   0900

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APPENDIX M. FATIGUE AVOIDANCE SCHEDULING TOOL (FAST) PRINTOUTS FOR ALL PARTICIPANTS

File   Edit   View   Display Options   Model   Window   Help

Open   New   Save   Copy   Print   View   Event   Auto Sleep   Help   Fatigue Facts   Exit

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of Transportation
Federal Railroad
Administration

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and
SAIC

Tue 012902	Wed 013002	Thu 013102	Fri 020102	Sat 020202	Sun 020302	Mon 020402

Effectiveness (%)

Blood Alcohol Equivalent (%)

Name: STENNIS(05MU)
Description:
Duration (days): 7
Automatic Phase Shift: ON
Starting Date: 02/01/2002
Zulu Delta: -6
Starting Latitude: 29° 32' N
Starting Longitude: 98° 28' W
Version: 5
Imported Sleep Data
 2/1/2002 9:01:00 PM

Awake Start	Duration	Mean Effec.	Work Start	Duration	Mean Effec.
0 - 01:57	912	78.38	0 - 09:00	488	78.94
0 - 20:39	191	79.18	0 - 20:39	191	79.18
1 - 02:23	928	77.08	1 - 02:23	928	77.08
1 - 18:59	18	80.02	1 - 18:59	18	80.02
1 - 21:08	31	79.63	1 - 21:08	31	79.63
2 - 00:41	895	74.67	2 - 00:41	895	74.67
2 - 19:06	126	85.41	2 - 19:06	126	85.41
2 - 23:44	1184	72.52	2 - 23:45	555	72.04
4 - 01:57	1051	77.49			
5 - 01:57	1051	81.08			
6 - 01:57	1324	80.29			

Work
Sleep
Base

06   12   18   00   06   12   18   00   06   12   18   00   06   12   18   00   06   12   18   00   06   12   18   00   06   12   18   00   06   12   18

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Fatigue Avoidance Scheduling Tool - Transportation Rail version - [STENNIS(44MU).fas]

File Edit View Display Options Model Window Help

Open New Save Copy Print View Event Auto Sleep Help Fatigue Facts Exit

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Federal Railroad Administration

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| Wed 013002 | Thu 013102 | Fri 020102 | Sat 020202 | Sun 020302 | Mon 020402 | Tue 020502 |

Effectiveness (%)

Blood Alcohol Equivalent (%)

Awake			Work		
Start	Duration	Mean Effec.	Start	Duration	Mean Effec.
0 - 00:01	531	70.76	0 - 03:00	351	65.82
0 - 18:39	959	85.61	0 - 18:39	959	85.61
1 - 19:39	990	85.73	1 - 19:39	990	85.73
2 - 19:16	917	85.00	2 - 19:16	464	96.07
3 - 17:02	1051	83.62			
4 - 17:02	1051	82.78			
5 - 17:02	1859	75.18			

Name: STENNIS(44MU)
Description:
Duration (days): 7
Automatic Phase Shift: ON
Starting Date: 02/02/2002
Zulu Delta: -6
Starting Latitude: 29° 32' N
Starting Longitude: 98° 28' W
Version: 5
Imported Sleep Data
2/1/2002 9:01:00 PM

Work
Sleep
Base

06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18

File Edit View Display Options Model Window Help

Open New Save Copy Print View Event Auto Sleep Help Fatigue Facts Exit

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| Tue 012902 | Wed 013002 | Thu 013102 | Fri 020102 | Sat 020202 | Sun 020302 | Mon 020402 |

Name: STENNIS(49MU)
Description:
Duration (days): 7
Automatic Phase Shift: ON
Starting Date: 02/01/2002
Zulu Delta: -6
Starting Latitude: 29° 32' N
Starting Longitude: 98° 28' W
Version: 5
Imported Sleep Data
 2/1/2002 9:01:00 PM

Awake			Work		
Start	Duration	Mean Effec.	Start	Duration	Mean Effec.
0 - 00:01	705	69.75	0 - 09:00	165	67.07
0 - 18:09	988	78.95	0 - 18:09	988	78.95
1 - 19:31	891	84.92	1 - 19:31	891	84.92
2 - 19:53	714	91.78	2 - 19:53	714	91.78
3 - 08:46	1523	71.98	3 - 08:46	14	71.69
4 - 16:38	1051	76.91			
5 - 16:38	1051	80.64			
6 - 16:38	443	89.35			

Effectiveness (%)

Blood Alcohol Equivalent (%)

Work
Sleep
Base

06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 0

Fatigue Avoidance Scheduling Tool - Transportation Rail version - [STENNIS(206MU).fas   ]

File   Edit   View   Display Options   Model   Window   Help

Open   New   Save   Copy   Print   View   Event   Auto Sleep   Help   Fatigue Facts   Exit

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| Fri 020102 | Sat 020202 | Sun 020302 | Mon 020402 | Tue 020502 |

Effectiveness (%)

Blood Alcohol Equivalent (%)

Name: STENNIS(206MU)
Description:
Duration (days): 5
Automatic Phase Shift: ON
Starting Date: 02/03/2002
Zulu Delta: -6
Starting Latitude: 29° 32' N
Starting Longitude: 98° 28' W
Version: 5
Imported Sleep Data
2/1/2002 9:01:00 PM

Awake			Work		
Start	Duration	Mean Effec.	Start	Duration	Mean Effec.
0 - 00:01	374	72.48	0 - 03:00	195	65.88
0 - 12:52	1112	84.56	0 - 12:52	1112	84.56
1 - 14:06	1003	86.27	1 - 14:06	774	90.62
2 - 13:18	1051	87.26			
3 - 13:18	1051	87.96			
4 - 13:18	643	91.82			

Work
Sleep
Base

0   06   12   18   00   06   12   18   00   06   12   18   00   06   12   18   00   06   12   18   0

File   Edit   View   Display Options   Model   Window   Help

Open   New   Save   Copy   Print   View   Event   Auto Sleep   Help   Fatigue Facts   Exit

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and
SAIC

Wed
013002

Thu
013102

Fri
020102

Sat
020202

Sun
020302

Mon
020402

Tue
020502

Effectiveness (%)

Blood Alcohol Equivalent (%)

100

75

50

25

.00
.04
.06
.08
.09
.10
.11
.12
.13
.14
.15

Name: STENNIS(24cMA)
Description:
Duration (days): 7
Automatic Phase Shift: ON
Starting Date: 02/01/2002
Zulu Delta: -6
Starting Latitude: 29° 32' N
Starting Longitude: 98° 28' W
Version: 5

Awake			Work		
Start	Duration	Mean Effec.	Start	Duration	Mean Effec.
0 - 00:01	1018	55.42	0 - 12:00	298	55.96
0 - 20:48	595	54.90	0 - 20:48	595	54.90
1 - 07:29	461	56.61	1 - 07:29	461	56.61
1 - 18:12	1455	53.03	1 - 18:12	1455	53.03
3 - 04:20	693	83.98	3 - 04:20	693	83.98
3 - 19:14	1242	70.11	3 - 19:14	1006	70.71
4 - 20:06	1190	62.17			
5 - 20:06	1190	58.01			
6 - 20:06	235	62.03			

Work
Sleep
Base

0   06   18   00   06   12   18   00   06   12   18   00   06   12   18   00   06   12   18   00   06   12   18   00   06   18   0

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File   Edit   View   Display Options   Model   Window   Help

Open   New   Save   Copy   Print   View   Event   Auto Sleep   Help   Fatigue Facts   Exit

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Effectiveness (%)

Blood Alcohol Equivalent (%)

| Tue 012902 | Wed 013002 | Thu 013102 | Fri 020102 | Sat 020202 | Sun 020302 | Mon 020402 |

Name: STENNIS(10FA)
Description:
Duration (days): 7
Automatic Phase Shift: ON
Starting Date: 02/01/2002
Zulu Delta: -6
Starting Latitude: 29° 32' N
Starting Longitude: 98° 28' W
Version: 5

Awake			Work		
Start	Duration	Mean Effec.	Start	Duration	Mean Effec.
0 - 00:01	766	68.81	0 - 12:00	46	67.55
0 - 16:58	81	88.11	0 - 16:58	81	88.11
0 - 19:40	176	84.51	0 - 19:40	176	84.51
1 - 00:10	428	70.63	1 - 00:10	428	70.63
1 - 09:30	1847	66.42	1 - 09:30	150	79.84
2 - 22:37	1060	64.01			
3 - 22:37	1060	67.64			
4 - 22:37	2964	54.95			

Work
Sleep
Base

06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18

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